Rebecca J. Dulin
Associate General Counsel

Duke Energy
1201 Main Street
Capital Center Building
Suite 1180
Columbia, SC 29201

o: 803.988.7130
f: 803.988.7123

Rebecca.Dulin@duke-energy.com

November 25, 2020

VIA ELECTRONIC FILING

The Honorable Jocelyn G. Boyd
Chief Clerk/Executive Director
Public Service Commission of South Carolina
101 Executive Center Drive, Suite 100
Columbia, SC 29210

Re: Petition of Duke Energy Carolinas, LLC and Duke Energy Progress, LLC for Approval of CPRE Queue Number Proposal, Limited Waiver of Generator Interconnection Procedures, and Request for Expedited Review
Docket No. 2018-202-E

Dear Ms. Boyd:

Pursuant to the Public Service Commission of South Carolina's ("Commission") Order No. 2019-247 issued on April 9, 2019, in the above-captioned docket, Duke Energy Carolinas, LLC and Duke Energy Progress, LLC (collectively, the "Companies") hereby respectfully provide the Commission an update on the Companies' most recent Distributed Energy Resources ("DER") Technical Standards Review Group ("TSRG") meeting held on October 28, 2020.

The following attachments enclosed with this update provide a more detailed account of the previous TSRG meeting and issues discussed:

- **Attachment A:** October 28, 2020 Meeting Agenda
- **Attachment B:** October 28, 2020 Minutes and Attendance
- **Attachment C:** Inverter Volt-Var Study Update
- **Attachment D:** Update and Discussion-Action Plan to Implement 1547-2018
- **Attachment E:** Periodic Self-Inspection Plan Update
- **Attachment F:** Implementation of IEEE 1547-2018 Guidelines (Redline)
- **Attachment G:** Implementation of IEEE 1547-2018 Guidelines (Clean)

As described in the Companies' June 6, 2019 Report in this docket, the TSRG webpage, https://www.duke-energy.com/business/products/renewables/generate-your-own/tsrg, provides meeting materials from each prior TSRG meeting, as well as other technical standards documents. The next TSRG meeting is tentatively scheduled for January 20, 2021.

Sincerely,

Rebecca J. Dulin

Attachments

C: Parties of Record (via email w/ attachments)

Attachment A

Interconnection Technical Standards Review Group (TSRG)
Duke Energy Carolinas/Progress
Meeting Agenda
October 28, 2020

In-person meeting converted to web meeting to follow distancing guidelines for COVID-19

9:00	Safety & Welcome – Wes Davis, Duke
9:05	IEEE 1547 implementation plan – Anthony Williams, Duke
9:30	Periodic self-inspection plan update – Kevin Chen, Duke
10:30	Break
10:45	Second Volt-VAR study scope – Anthony Williams, Duke
11:30	Additional discussion on topics
	DG Location Guidance Map
	Others, as needed
11:55	Wrap up & next meeting date – Wes Davis, Duke (Recommend Jan 19,20)
12:00	ADJOURN

Duke Energy Carolinas/Progress Interconnection Technical Standards Review Group (TSRG)

Meeting Minutes

October 28, 2020

I. Opening

This is a regular meeting called to order at 9:01 AM via Microsoft Teams

Meeting facilitator: Anthony Williams

Minutes: Jonathon Rhyne

II. Record of Attendance

Member Attendance

Name	Affiliation	Attendance
Anthony Williams	Duke Energy	Present
Jonathon Rhyne	Duke Energy	Present
Wes Davis	Duke Energy	Present
Jonathan Demay	Duke Energy	Present
Orvane Piper	Duke Energy	Present
Scott Griffith	Duke Energy	Present
Huimin Li	Duke Energy	Present
Kevin Chen	Duke Energy	Present
Bill Quaintance	Duke Energy	Present
Stephen Barkaszi	Duke Energy	Present
John Gajda	Strata Solar/NCCEBA	Present
Bruce Fowler	BAM Energy	Present
Chris Sandifer	Embarq	Present
Tommy Williamson	Public Staff	Present
Devin Van Zandt	EPRI	Present
Staci Haggis	Advanced Energy	Present
Chuck Ladd	Ecoplexus	Present
Luke O'Dea	Cypress Creek Renewables	Present
Paul Brucke	NCSEA	Present
Craig Munger	Cypress Creek Renewables	Present
Rob Lawyer	ORS SC	Present
Ben Brigman	Ecoplexus	Present
Wei Ren	EPRI	Present
Sean Grier	Duke Energy	Present

III. Current agenda items and discussion

9:00	Safety & Welcome – Wes Davis, Duke Energy
9:05	IEEE 1547 Implementation plan – Anthony Williams, Duke Energy
9:30	Periodic self-inspection plan update – Kevin Chen, Duke Energy
10:30	Break
10:45	Second Volt-VAR study scope – Anthony Williams, Duke Energy
11:30	Additional discussion on topics
	DG Location Guidance Map
	Others, as needed
11:55	Wrap up & next meeting date – Wes Davis, Duke Energy
12:00	Adjourn

1) PRESENTATION: IEEE 1547 Implementation plan – Anthony Williams, Duke Energy
   A) Presentation provided with minutes
   B) Q&A:

      Q – Section 7.4 Overvoltage capability (Pg. 24) of red line, did Duke mean to have this text in 7.3 for harmonics?
      Duke – Duke will review notes for sections 7.3 and 7.4 and verify everything is in the proper section.

      Q – Also Section 5.2 reactive power capability Cat B PF 0.9 with ambient temperature of 35C or lower. Also noted as the same as transmission, but IEEE 2800 is going with 0.95.
      Duke – Duke will clarify the differences between the IEEE requirements and Duke requirements. Duke will clarify the differences between the requirements and the format of the reactive power capability reporting requirements.

      Q – Must the DER meet a temperature requirement 35C or higher?
      Duke – No. A DER may submit a 40C curve, but it is not required. Duke will clarify the differences between the requirements and the format of the reactive power capability reporting requirements.

      Q – Is 0.9 requirement at PCC or Inverter terminals?
      Duke – Category B is an IEEE equipment capability, so it is at the inverter terminals. All Duke requirements are at the RPA.

Q – When will the new requirements apply to new to DER interconnections? Will any be retroactive.
Duke – No dates chosen yet. Duke will accept suggestions as to the implementation dates. Duke will work with the industry to provide sufficient time to design facilities to the new requirements.

Q – If IA in place are the new rules not applicable to DER?
Duke – Not applicable. Duke tradition has been not to make requirements retroactive. However, if new rules benefit the facility and the facility would like to adopt the new standards, then Duke is open to discussing that option to see if it is viable.

Q – The state interconnection agreements do not align with Cat B pf.
Duke – There must be IA & IP updates to incorporate the changes to adopt the standard [IEEE 1547-2018].

Q – 3rd Paragraph 44% of nameplate based on nameplate of inverters? What if… Developer has 5MW project, but 6MW of inverter capacity? Critically important for developers to understand, so they meet requirements without active power reduction.
Duke – The wording is taken directly as stated in the Standard. More discussion on this is required to reconcile the Standard requirements and Industry request. Duke will attempt some changes to the section. [Possibly the revised 1547.2 will address this gap between the rated kW and the rated kVA.]

2. PRESENTATION: Periodic self-inspection plan update – Kevin Chen, Duke Energy
   A) Presentation provided with minutes
   B) Q&A:
      Q – Has Duke thought through what is expected of the volunteers? What is Duke expecting from pilot? Specific things Duke is looking for?
      Duke – Run training agenda by TSRG and what is should cover.

   C) Comments:
      Industry – Advocates opening of TSRG group to all developers. Encourage reach out to folks not involved in TSRG to connect with wider group.

      Duke – TSRG membership is focused on the DER industry in the Carolinas. TSRG to includes people actively connecting projects now. There are concerns with bringing a new group of non-engineers up to speed on technical issues. It is not clear how expanding would be better than what is done now.

      Industry – Make folks aware of meeting notes and they can listen in.
      Duke – The members bring questions/concerns to meeting.

3. PRESENTATION: Second Volt-VAR study scope – Anthony Williams, Duke Energy
   A) Presentation provided with minutes
   B) Q&A:

      Q – What will be the approach to sifting through data to evaluate the results? What is actionable?
      Duke – That is what the metrics are for. Several characteristics are noted to be monitored during the studies, so let us know if know of a metric we should measure that we currently do not plan to monitor. What metrics are most helpful to measure? Going into the study, the main objective is to maintain voltage below limit and minimize the magnitude and duration of VAR consumption.

      Q – There are different methods to control voltage, how effective is each method? Absorption occurs at off peak, is that bad? Do we have to avoid?
      Duke – The metrics will be used to compare the control methods and settings. If the system needs more VAR demand during off peak times, then the reactive consumption is not as impactful to system operation. However, the first study showed that once the voltage increases, that it often stays high. That means that most of the reactive power absorbed during light load is still there during peak load, which is less desirable. It was also noted that reversing current creates voltage rise anytime that occurs.

      Q – Volt/Var less effective closer to substation?
      Duke – Yes, as seen in the first study. Time series can quantify the magnitude and duration of the VAR absorption to compare with the voltage change provided [effectiveness of the reactive power to control voltage].

4. DISCUSSION TOPICS: DG location guidance map update – Wes Davis, Duke Energy
   A) The guidance map is now available. Provides a geographical view and is consistent with the Method of Service Guidelines.
      Brief overview of methodology & legal disclaimer.
      Link below:
      https://www.duke-energy.com/business/products/renewables/generate-your-own/interconnection-more-than-20kw

the Supplemental Review is not deemed to be required, the Supplemental deposit payment will be refunded. A Summary of the Criteria used in Supplemental Review is provided for information purposes.

System Constraints and Locational Guidance

Distribution

The new Distribution Generation locational guidance map is now available! This map provides a geographical visualization of the distribution system in a manner consistent with the Duke Energy Renewables Method of Service Guidelines to inform siting of distributed generation (DG) sites greater than 20 kW. The disclaimer included along with the map contains necessary and important contextual information for using the map. The map is a feeder and bank-level snapshot of the distribution grid with shading to represent cumulative constraints (based on installed and queued DG facilities) and cross-hatching to indicate individual site size limits.

Map and methodology guide may be accessed via the following links:

DG Locational Guidance Map for Distribution System
DG Locational Guidance Map – Methodology Guide

Transmission

Information on constraints on the transmission system is also available. Maps of the approximate location of the •filOs 1n Ouk• f.nt.f8'J Cnrolm,01 ond Oukt (r-e,gy P1os1tM, ttlol

5. Date for the next meeting and location
    a. Dates for the next meeting were discussed (Recommend Jan 19th, 20th)
    b. The next meeting is expected to be online rather than in person because of COVID
    c. The agenda is open now for potential items for discussion.
    d. It was asked to consider keeping the virtual format even after COVID to reduce travel difficulties/conflicts.

6. The meeting concluded at 12:14 PM

Attachment C

TSRG: Inverter Volt-VAR Study Update

Anthony C Williams, DER Technical Standards

October 28, 2020

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Second Study Overview

- More emphasis on higher voltage feeders so that less DER forces the overvoltage
- Calculate P and Q responses
- Consider a broader variety of controller types
  - Limited controller setting variations: approximately 6 volt-var, 8 pf, 5 watt-var
  - Continued use of volt-watt to backup the primary controller
- Expand the attributes monitored during the study; to inform conclusions
- Quasi-Static Time Series (QSTS) simulation using 8760 hourly load and solar profile
- Compare monitored attributes across the feeders for the various controller types
  - Inform policy development to guide application of DER voltage and reactive power controls, and
  - Develop methods to a) provide a quick assessment of reactive power control effectiveness at a potential UDER interconnection point, and b) indicate the most appropriate type of control
- Interim update at October TSRG
- Final report February, presentation at the following TSRG

Feeder Selection

- Attributes that may indicate feeders more relevant for volt-VAR studies
  - Initial system voltage near voltage limit
  - Short circuit MVA at the PCC – low, typical, high
  - DER kW on the feeder (not penetration)
  - Upstream voltage regulation devices with droop compensation
- Weighted
- Sorted by feeders with the highest value

Attachment C

P and Q responses

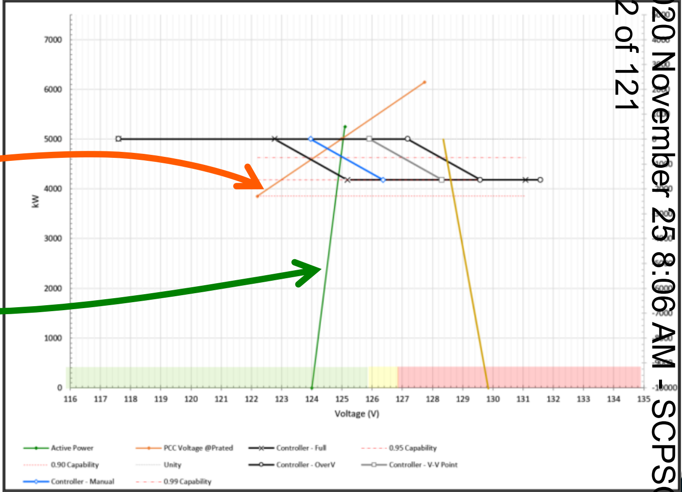
1. Using data from a few operating points

(- means sending to grid)	PCC Voltage			PCC		Inverter	
	A	B	C	P	Q	P	Q
P=0S, Q=0S	126.1	125.8	125.7	0	0	0	0
P=1S, Q=0S	127	126.7	126.6	-5020	254	-5040	0
P=0.9S, Q=-0.44S	124	123.7	123.6	-4514	2475	-4536	2196
P=0.9S, Q=0.44S	129.8	129.5	129.4	-4517	-1964	-4536	-2198

2. Several characteristics of the feeder can be determined

kVA	5040
Presp = dV/Psys	0.15%
Pctrl = dV/Prated	0.68%
dV/Prated	0.81
Qresp = dV/Qsys	1.13%
Qctrl = dV/Qrated	2.47%
dV/Qrated	2.97
Qresp/Presp	7.53
Qrated/Prated	*3.65*
Q/P OV	*9.05*
SCC	86.2
X	1.15
X/R	6.23

3. To assist with evaluating the initial settings



Attachment C

Sample of Controller Configurations

- power factor control (pf)
  - Baseline options
    - 1.0 pf (0%)
    - 0.95 pf (31%)
    - 0.90 pf (44%)
  - Full compensation (offset voltage change at Prated)
  - Overvoltage compensation (offset overvoltage at Prated)
    - A good limiting case, but probably not a practical case
  - Likely adding a few more pf points across the range of interest will be most useful; provide a common baseline
    - 0.97 (24%)
    - 0.98 (20%)
    - 0.99 (14%)

Attachment C

Sample of Controller Configurations

- voltage – reactive power control (v-var)
  - Baseline options
    - IEEE default A and B
    - Study 1 setting, 1.04 pu, 2% slope to Qrated
  - Continue the Boundary cases
    - Full compensation (offset voltage change at Prated)
    - Overvoltage compensation (offset overvoltage at Prated)
  - Considering other standardized controls, for example
    - A setting that exhausts reactive capability at voltage limit
    - May adopt a standard range here too, like with pf
      - Spread the settings across a range: 1.02, 1.03, and 1.04.

Sample of Controller Configurations

- active power control – reactive power control (watt-var)
  - Baseline options
    - Use a pf control
    - IEEE default A and B
  - Continue the Boundary cases
    - Full compensation (offset voltage change at Prated)
    - Overvoltage compensation (offset overvoltage at Prated)
  - Consider variations that delay reactive compensation until higher active power levels
- voltage – active power control (v-watt)
  - Settings from first study: 1.06 puV, 0 puQ : 1.09puV, -0.312 puQ
  - Expect to use it as a secondary to the primary controller, except for
  - May use at feeder head DER locations where reactive power is not effective

Attachment C

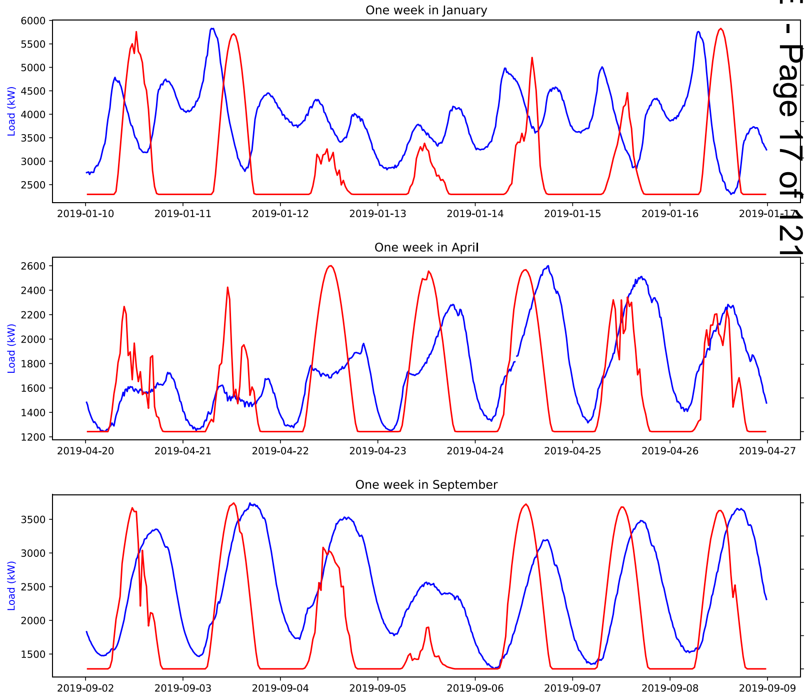
Metrics

▪ Site specific (fixed) ▪ Rated Pgen, Qgen at PCC and inverter ▪ SCC at Station, PCC ▪ X, from PCC back to source ▪ R, from PCC back to source ▪ PCC Voltage, Basecase (P=Q=0) ▪ PCC Voltage, Initial (P=Prated, Q=0) ▪ Min load kva/Peak load kva ▪ Feeder head power flow, kW and kVAR ▪ ΔV/ΔP (Presp, derivative of voltage variation to real power injection) ▪ ΔV/ΔQ (Qresp, derivative of voltage variation to reactive power injection) ▪ Qresp/Presp = (dV/dQ) / (dV/dP) ▪ ΔV/ΔPrated (total voltage change at rated active power) ▪ ΔV/ΔQrated (total voltage change at rated reactive power)	▪ Controller specific ▪ Overvoltage Magnitude, PCC, Feeder, Inverter (V) ▪ Overvoltage Occurrences, PCC, Feeder, Inverter ▪ Feeder Active Power Max, Min (kW) ▪ Feeder Reactive Power, Max, Min (kVAR) ▪ Total MWh, MVARh, at PCC, Inverter ▪ Tradeoff MW, MWh

Attachment C

Quasi-Static Time Series (QSTS) Model

- 8760-hour load profile developed from DEC and DEP measurements (for year 2019)
- Solar taken from the NREL NSRDB database (at each feeder zip code and for year 2019)
- Feeder voltage regulation (e.g., LTC, VR, CB)
  - Local control as in the original CYME models
- Inverter control
  - Q priority (i.e., active power restricted if needed)
  - Q cut-in power level = 5% of inverter rating
- Baseline case definition
  - No injection from the PV under study while all other existing PVs generate power
- Smart Inverter functions in evaluation
  - Constant Power Factor
  - Volt-Var
  - Watt-Var

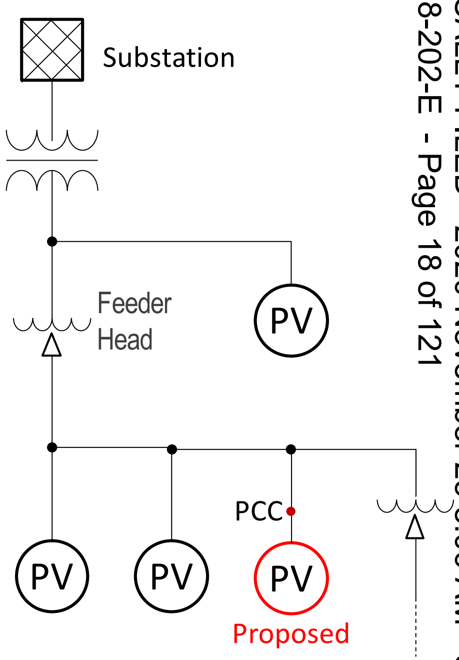


Attachment C

Time Series Preliminary Results

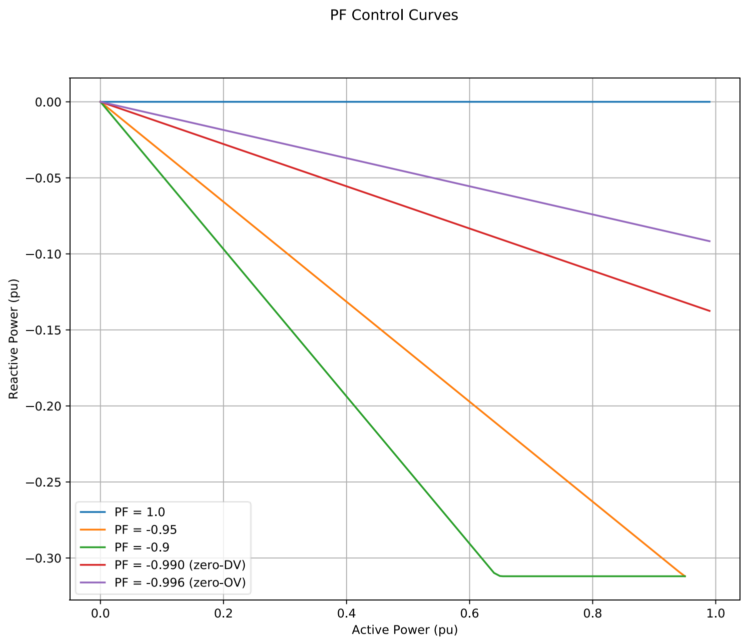
Feeder A Characterization Table

Parameter	Value
Feeder peak load	6.85 MW (PF = 0.995)
Connected DERs	Three existing and one proposed (5.5MVA each)
R_PCC (pu @ 1MVA)	0.0018
X_PCC (pu @ 1MVA)	0.011
∂V / ∂P (puV / 1MW)	0.0014 (-0.0005 ~ 0.0014 depending on load/gen levels)
∂V / ∂Q (puV / 1MVAr)	0.0110 (0.0105 ~ 0.0110 depending on load/gen levels)



Attachment C

Constant Power Factor Control Mode Comparison

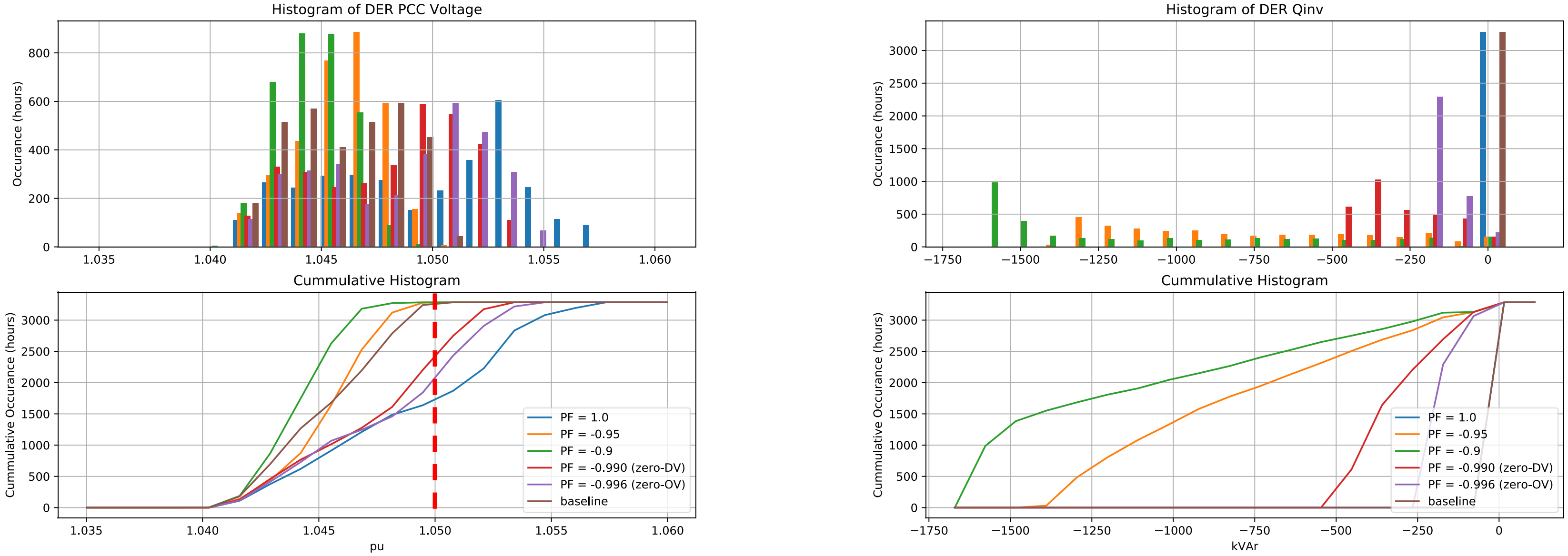


	PF=1.0	PF=-0.95	PF=-0.9	PF=-0.990 (zero-DV)	PF=-0.996 (zero-OV)
Max V_PCC (pu)	1.058	1.050	1.049	1.054	1.055
DER MWh	8472	8465	8459	8472	8472
DER MVArh	0	-2775	-3798	-1173	-782
Max Tradeoff MW	0.0	0.2	0.3	0.0	0.0
Tradeoff MWh	0.2	7.6	14.7	0.4	0.2
Feeder Loss MWh	268 +179	268 +176	268 +178	268 +176	268 +177
Feeder Loss MVArh	2517 +1573	2517 +1596	2517 +1625	2517 +1569	2517 +1568

- Inverter clamps Q at 31.2% as its specified limit (equivalent to 0.95 power factor)
- The worst-case (PF=-0.9) tradeoff MWh is 0.17% (i.e., 14.7MWh/8472MWh) of the total generation yield
- The difference between control modes on feeder loss is insignificant

Attachment C

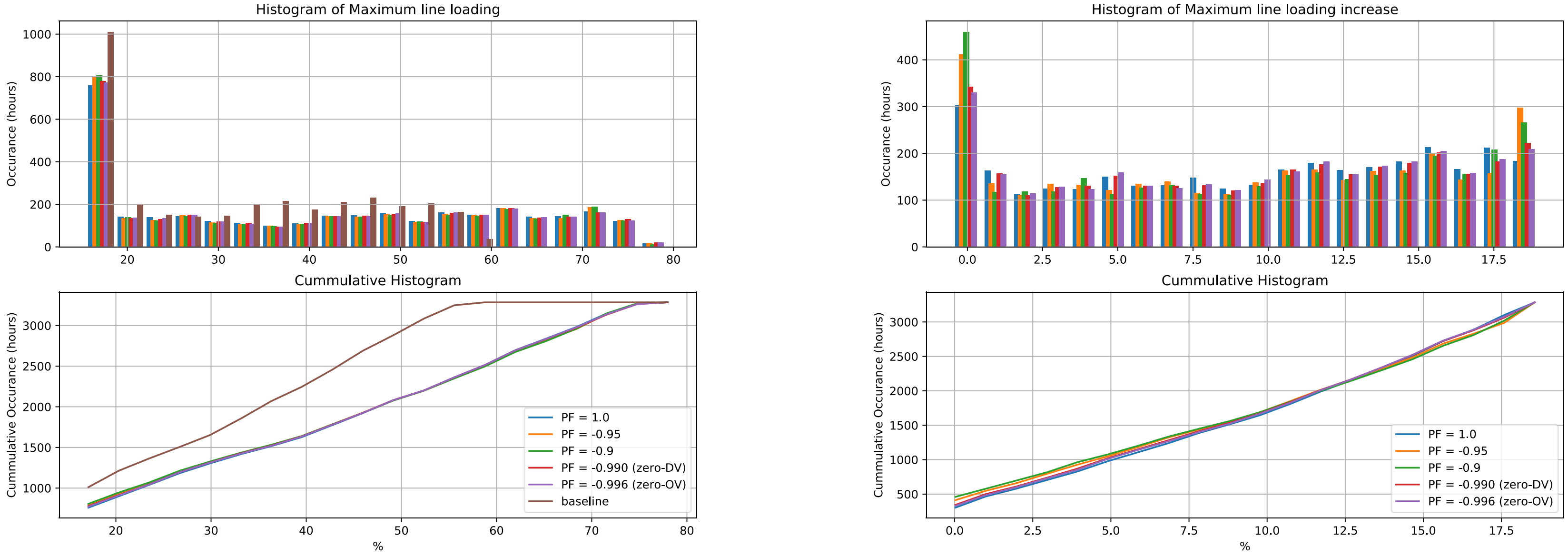
Constant Power Factor Control Mode (Continued)



- Only 9AM to 5PM daily hours for 365 days
- Baseline case means no power output from the proposed DER
- Zero-DV power factor still sees over-voltage due to the operation of line voltage regulator
- As power factor becomes more inductive, so does the absorbed Q increase

Attachment C

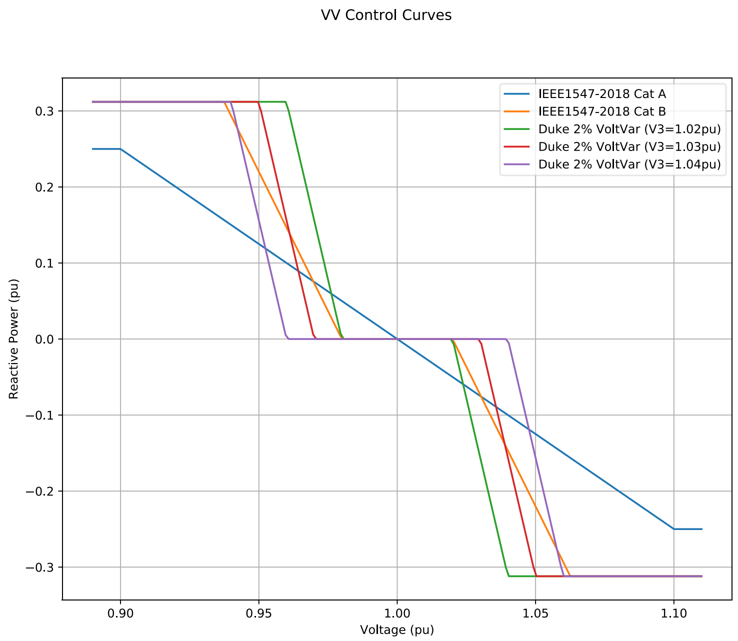
Constant Power Factor Control Mode (Continued)



- All power factor modes show similar increase (~17%) to the maximum line loading
- No over-loading is observed in this feeder due to the proposed DER

Attachment C

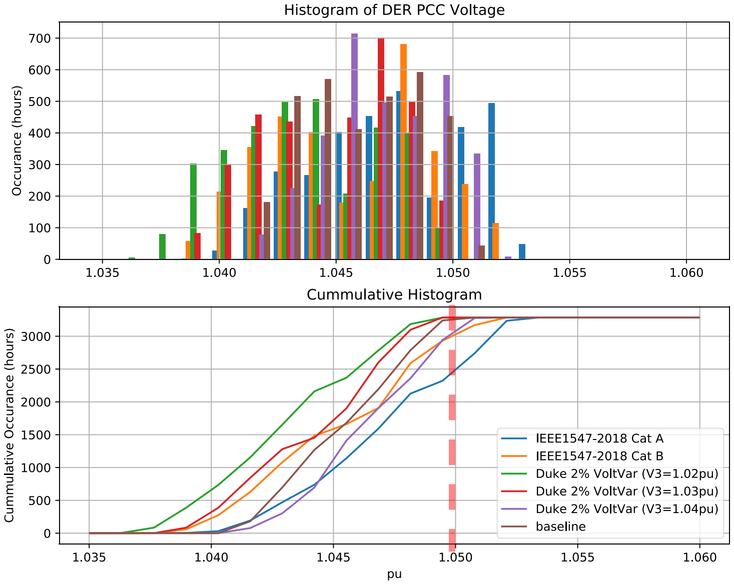
Volt-Var Control Mode

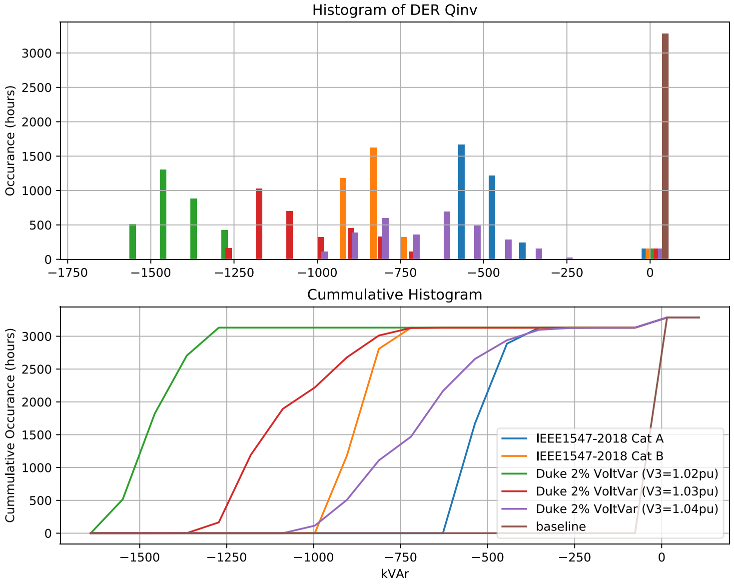


	1547 A	1547 B	2% V3=1.02	2% V3=1.03	2% V3=1.04
Max V_PCC (pu)	1.053	1.052	1.049	1.050	1.052
DER MWh	8472	8471	8466	8468	8472
DER MVArh	-1862	-2956	-4831	-3614	-1869
Max Tradeoff MW	0.0	0.1	0.2	0.2	0.1
Tradeoff MWh	0.3	1.6	7.1	4.4	0.8
Feeder Loss MWh	268 +174	268 +174	268 +177	268 +175	268 +175
Feeder Loss MVArh	2517 +1557	2517 +1571	2517 +1617	2517 +1591	2517 +11566

Attachment C

Volt-Var Control Mode (Continue)

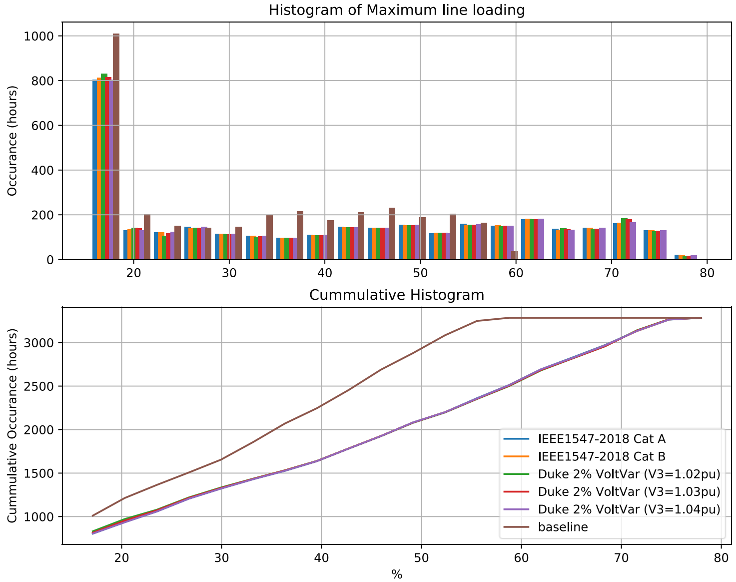


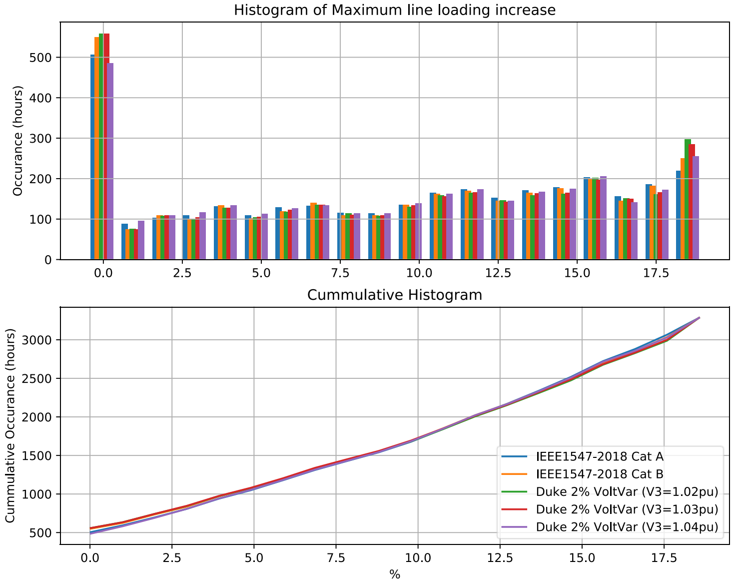


- Most options show lower number of over voltage hours as compared to power factor mode
- Earlier voltage regulation (V3=1.02 or 1.03) helps mitigate over voltage violation
- Steeper volt-var slope helps mitigate over voltage violations (1547-B vs. 2%-V3=1.02)

Attachment C

Volt-Var Control Mode (Continue)

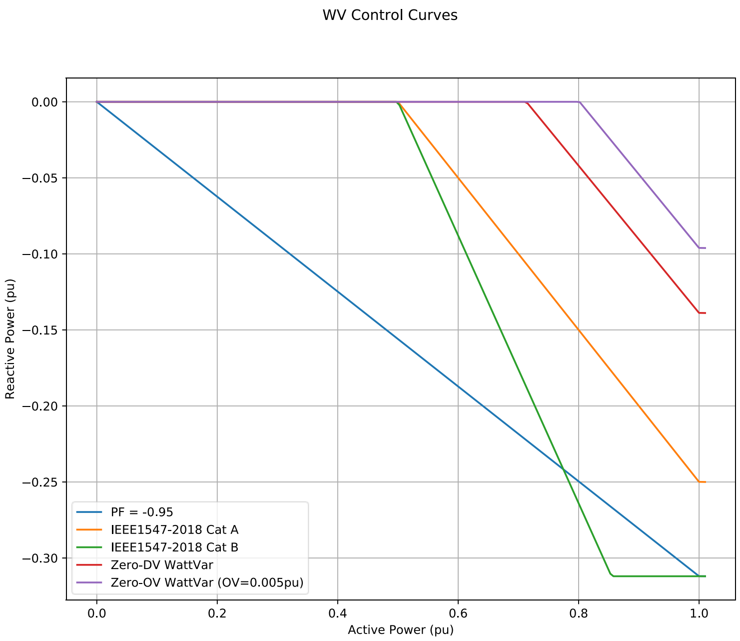




- All options show similar increase (~17%) to the maximum line loading
- No over-loading is observed in this feeder due to the proposed DER

Attachment C

Watt-Var Control Mode

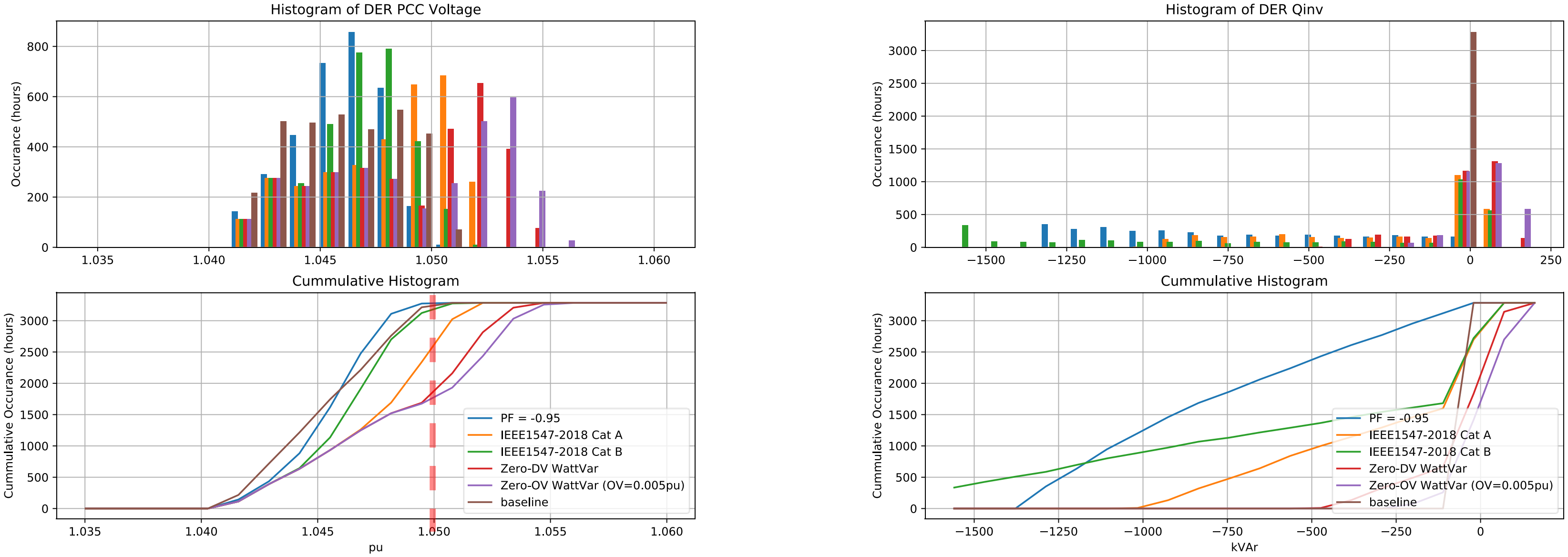


	PF=-0.95	1547 A	1547 B	Zero-DV	Zero-OV
Max V_PCC (pu)	1.050	1.053	1.052	1.055	1.056
DER MWh	8465	8470	8457	8472	8472
DER MVArh	-2775	-1112	-1914	-344	-155
Max Tradeoff MW	0.2	0.1	0.3	0.0	0.0
Tradeoff MWh	7.6	2.3	16.1	0.3	0.2
Feeder Loss MWh	268 +176	268 +178	268 +179	268 +178	268 +178
Feeder Loss MVArh	2517 +1596	2517 +1587	2517 +1615	2517 +1578	2517 +1575

- Watt-var is a non-linear version of constant power factor control
- With same Qmax at full power, watt-var 1547-B results in lower total DER MVArh than that of PF=-0.95 or PF=-0.9

Attachment C

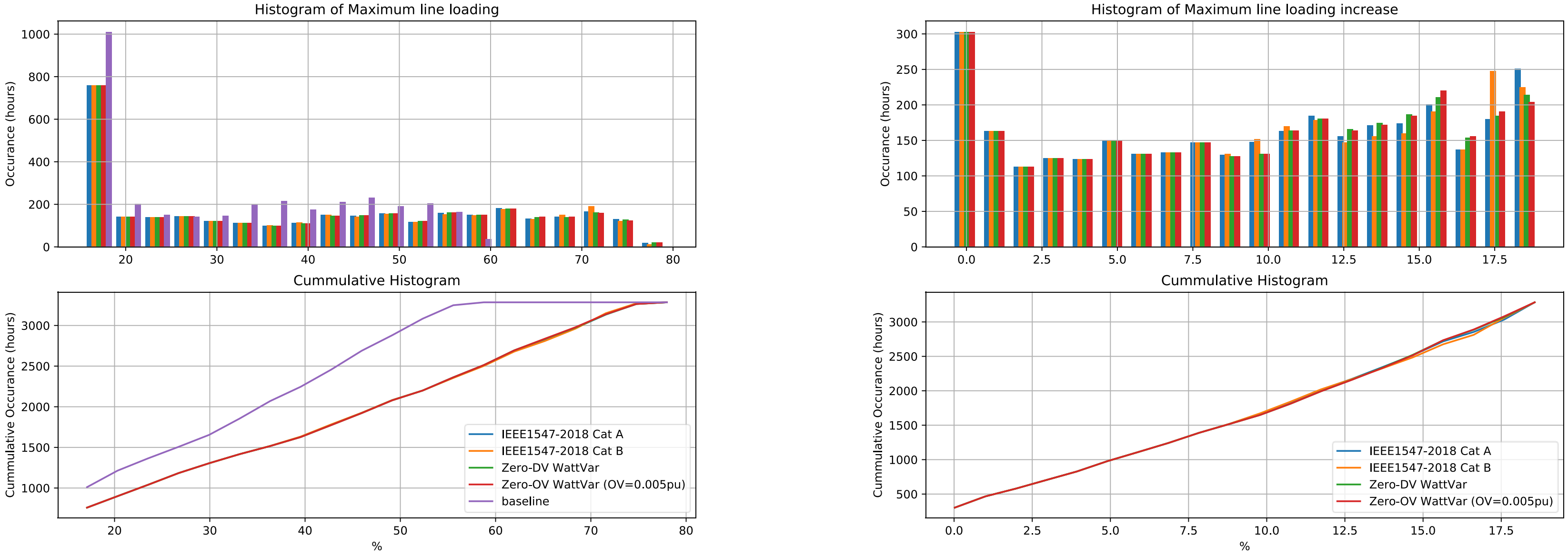
Watt-Var Control Mode (Continue)



- All options present over voltage hours in the simulated year
- Steeper watt-var slope and higher Q value help mitigate over voltage violations (as expected)

Attachment C

Watt-Var Control Mode (Continue)

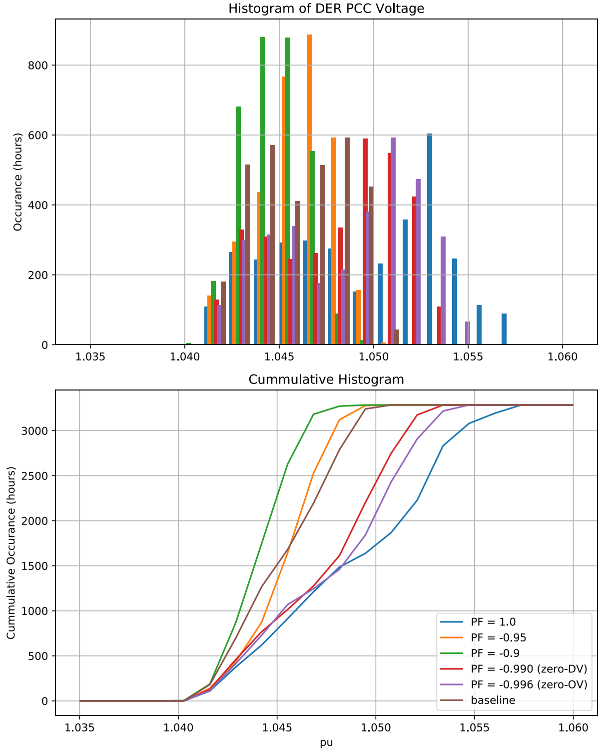


- All options show similar increase (~17%) to the maximum line loading
- No over-loading is observed in this feeder due to the proposed DER

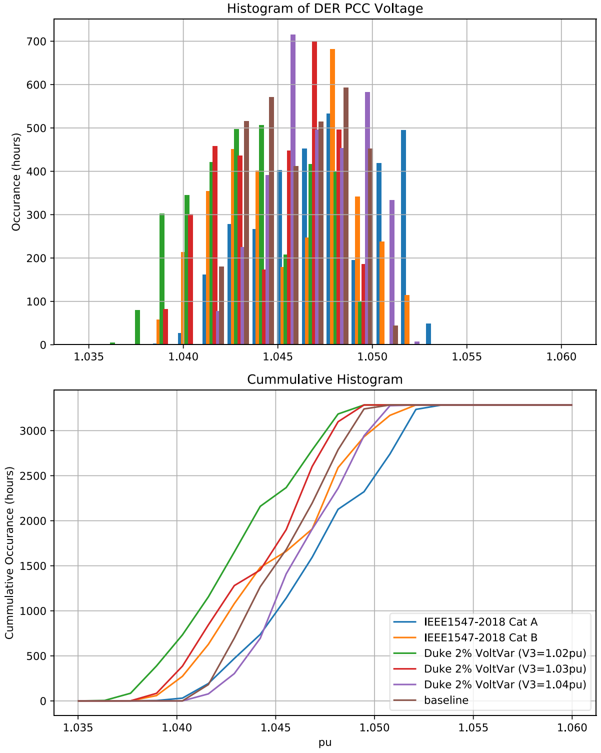
Attachment C

Comparison of Control Options

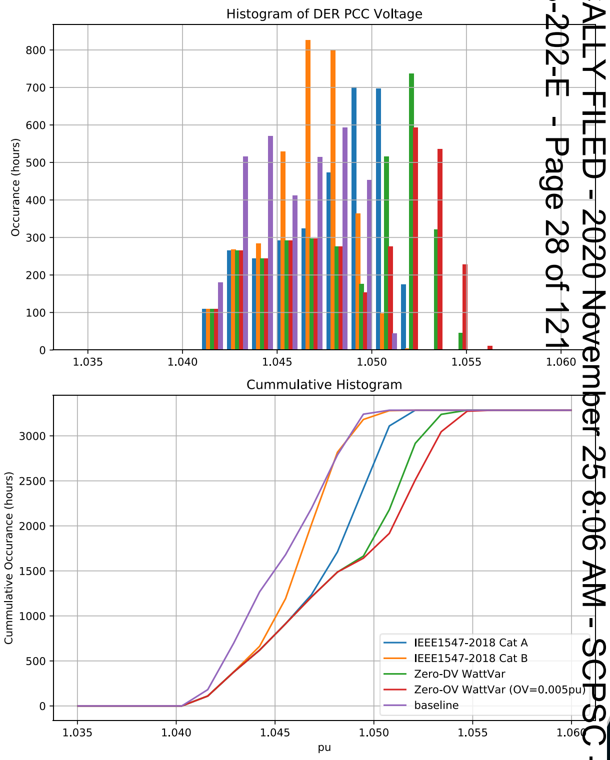
Constant PF



Volt-Var



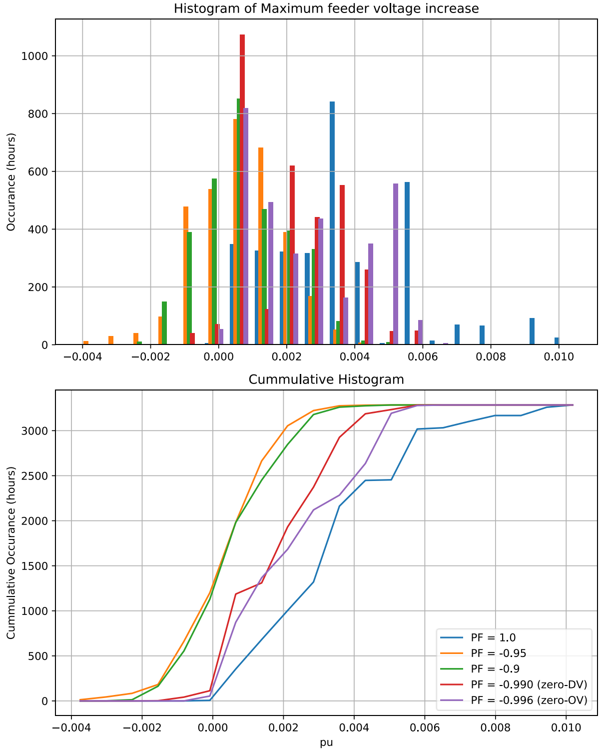
Watt-Var



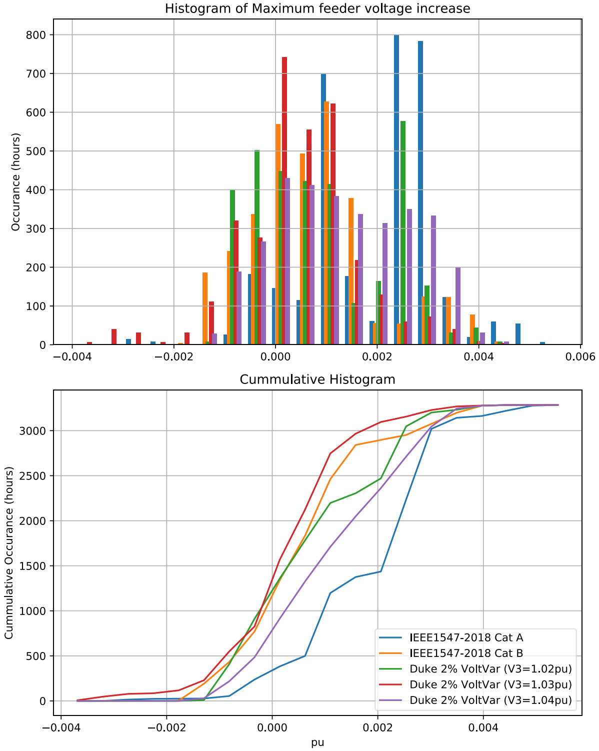
Attachment C

Comparison of Control Options (Continued)

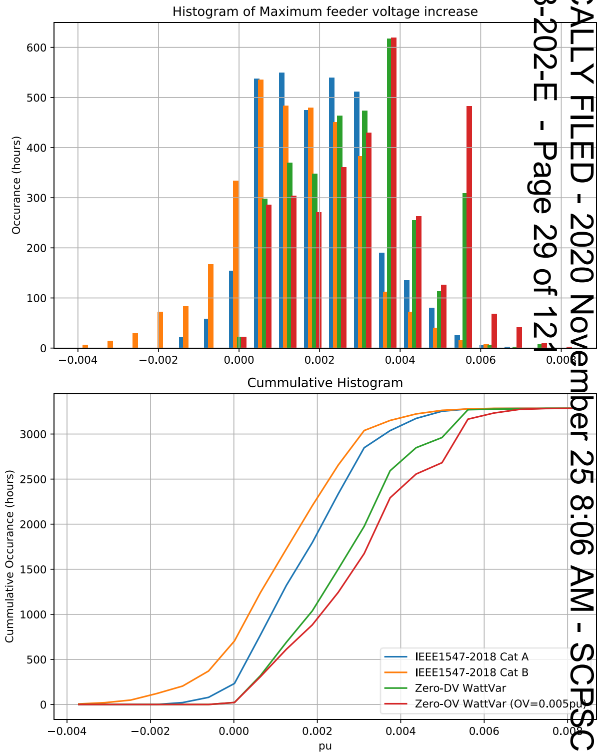
Constant PF



Volt-Var



Watt-Var



- Plots here show the maximum voltage increase on the feeder versus the baseline case

Attachment C

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Attachment D

Update and Discussion: Action Plan to Implement 1547-2018 TSRG Meeting

Anthony C Williams, P.E.
Principal Engineer

DER Technical Standards
October 28, 2020

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Agenda

- Review main revisions
  - Current version is "Duke Energy IEEE 1547 Implementation Guidelines, Rev 2"
    - Rev 1A is the redline version of Rev 2
- Discussion

Logistics

- Clarifying questions will be answered during the presentation and stakeholder discussions at the end of the presentation
- Written feedback and comments will be solicited using comment form
  - Note questions then lets discuss – don't really want all the questions sent in that are mainly just for clarification – this takes a lot of time to address that could be spent on the comments and recommendations
  - It would be helpful to provide more Comment and Proposed Change details :

Stakeholder Name	Page Number	Paragraph Number	Comment	Proposed Change
example Question format	3	2	Why is winter data excluded?	None
example Comment format	7	4	Agree with the hours of study.	None
example Comment format	7	4	'the largest' is not clear	Replace 'the largest' with 'the maximum of the three phase currents"
example Recommendation format	10	3	The types of faults is too limited. Include single line to ground faults.	Include SLG faults

  - Being more specific makes the point, or main concerns, of the comment more apparent and allows a more direct response.
- Comments will be taken during the discussion and the form will be distributed after the meeting
- Share the feedback form using email: Duke-IEEE1547@duke-energy.com for stakeholders to provide their written feedback

Priority Groups 1 – 5 Review

1st	• Reactive power and voltage control • Power quality
2nd	• Voltage tripping and ride through • Frequency tripping and ride through
3rd	• Most important sections of Section 4, General Tech Specs
4th	• Most commonly applied sections of Section 4, General Tech Specs
5th	• Remaining sections of Section 4, General Tech Specs

Priority Table Updates, Group 1

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test

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Priority Table Updates; Group 2

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test

Priority Group 1 Revisions

- All completed except the two associated with the voltage and reactive power control studies

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Priority Groups 2, 3, 4 Revisions

- DUK-13 Section 4.5 – Cease to energize performance requirement, ready to be implemented

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

~~For UDER, Duke Energy is still considering implementing the cease to energize at the inverter or disconnecting at the local EPS.~~

A DER can be directed to cease to energize and trip by changing the Permit service setting to "disabled" as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.~~The Binary Output is sent via SCADA to open inverter(s) breaker and is already implemented.~~

Priority Group >5 Updates

- DUK-26 Section 4.12 – Integration with Area EPS grounding, ready to be implemented

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below:

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection	
			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Summary

- Sections accepted as written in 1547
  - DUK-28 Section 4.8 – Isolation device
  - DUK-23 Section 4.9 – Inadvertent energization of the Area EPS
  - DUK-29 Section 4.11.1 – Protection from electromagnetic interference
  - DUK-30 Section 4.11.2 – Surge withstand performance
  - DUK-22 Section 4.11.3 – Paralleling device
- Sections completed
  - DUK-13 Section 4.5 – Cease to energize performance requirement
  - DUK-26 Section 4.12 – Integration with Area EPS grounding, ready to be implemented

  --- Sections previously completed ---
  - DUK-05 Section 7.2.3 – Flicker
  - DUK-04 Section 7.4 – Limitation of overvoltage contribution
  - DUK-01 Section 5.2 – Reactive power capability of the DER

Discussion

- Maintain focus on the Priority groups 1 and 2
  1. Continue with the inverter reactive power control studies
  2. Await conclusions from the ongoing study by the Protection and Transmission Planning groups
- Collect stakeholder input on the guidelines

Attachment D

Attachment E

Periodic Inspection Program
Self-inspection Plan – Update

Kevin Chen 10/28/2020

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Attachment E

Agenda

- 4th Quarter Solar Commissioning Update
- Self-inspection Process Update
- Expected Timeline
- Q&A, open discussion

Attachment E

4th Quarter Commissioning Update

- In the week of 10/12 – 10/16, Duke and AE reached out to every developer with a list of project status and schedule.
- All sites that are pending initial inspection have been scheduled. Everyone has booked a slot on the calendar.
- Duke is tracking utility side system upgrade closely to align with the customer's commissioning schedule. We will continue the proactive communication with each customer if there is risk or change in schedule.
- As of 10/27, there are 46 sites to be connected before the end of 2020.
  - The conditional commissioning process started from 10/1/2020.
  - It is critical for the developer to keep the scheduled inspection dates.

Agenda

- 4th Quarter Solar Commissioning Update
- Self-inspection Process Update
- Expected Timeline
- Q&A, open discussion

Attachment E

Documents shared in July 2020:

1. Comments resolution tracking sheet
2. Process document redline version in PDF
3. Process document clean version in PDF
4. Instruction manual redline version in PDF
5. Instruction manual clean version in PDF
6. Report template redline version in PDF
7. Report template clean version in WORD
8. Report template (device info and settings) in EXCEL

(Process document is under major revision to reflect the comments received and updates made since the September TSRG meeting.)

Additional material:

- Full list of issues from pilot periodic inspection in 2018 and 2019
  - It will be served as reference in the technical training.

Highlights of the Updates

- Under the framework of self-inspection, different types of self-inspection are defined.
- The cease-to-energize test is added to the self-inspection requirements for previously uninspected facilities.
  - The DER facility may be permitted to perform its own cease-to-energize testing when certain conditions are met.
- We are taking inputs from the industry in defining the self-certifying questions to be included in the annual self-inspection requirement.
- The MV AC construction quality inspection is not periodically required after a successful initial inspection.
  - It may be required on the as-needed basis if the facility is going through major re-construction or equipment change, or causing PQ/reliability issue.
- The DER periodic compliance re-verification and periodic interconnection test are included in the framework of self-inspection and pending further development.

Attachment E

The Framework of Self-inspection

Self-inspection

- Inspection is not only limited to the MV AC construction quality inspection.
- The term "self-inspection" here is to describe the activities that customers can choose any qualified resources to perform to meet the applicable requirements (as defined by NCIP, SCGIP, IEEE Std, etc.).

- Self-inspection for Previously Uninspected Generating Facilities
- Annual Self-inspection for Continuous Compliance Verification
- Periodic Self-inspection for Compliance Verification
- Self-inspection for Previously Inspected Generating Facilities After Significant Modification
- Self-inspection for Previously Inspected Generating Facilities After PQ/Reliability Event

Attachment E

Self-inspection for Previously Uninspected Generating Facilities

Description and General Requirements

- This program is designed to address risks around (a) MV construction quality and (b) facility response for "cease-to-energize capability," at the uninspected facilities. This program also includes DER as-built evaluation and Interconnection equipment settings check.

Activity/Requirement	Reference Standards	One-time or periodic	Applicable to
Self-inspection and report (require PE, follow the instruction manual): - MV AC side construction quality - DER as-built evaluation - Interconnection equipment device settings submitted to Duke Energy - Proof of clear POI access **Cease-to-energize test (anti-islanding function assessment)** - Default option, Duke to dispatch resource to perform the cease-to-energize test by operating Duke's interconnection facility. - Alternatively, The DER facility may be permitted to perform its own cease-to-energize testing when certain conditions are met.	NCIP-P 6.5.2 NCIP-IA 1.5.4 IEEE 1547 (2003) IEEE 1547.1 (2005)	One time Over the period 2021-2025	DER with IAs with no reference to Duke construction specifications (COD ~pre-2017) "Previously Uninspected Generating Facilities"

NCIP-P refers to the Procedures portion of the NCIP; NCIP-IA refers to the Interconnection Agreement portion of the NCIP

Attachment E

Annual Self-inspection for Continuous Compliance Verification

Description and General Requirements

- This is the periodic (annual) requirement applicable to all generating facilities post-commissioning and inspection, designed to assure continuing DER compliance.

Activity/Requirement	Reference Standards	One-time or periodic	Applicable to
Provide the following items to Duke every year, not requiring PE: - Interconnection equipment settings using the Excel template - Photo proof of clear access to Duke POI - Answers to a list of self-certifying questions	NCIP-P 6.5.3 NCIP-P Attachment 4 (IEEE 1547)	Periodic (annual)	All DER post commissioning

Attachment E

Periodic Self-inspection for Compliance Verification

Description and General Requirements (Under Development)

- Duke intends to require periodic (longer interval TBD) inspection with a PE-prepared report, together with periodic testing.
- Duke is working closely with the industry and peer utilities on this topic of periodic requirements on DER facilities.

Activity/Requirement	Reference Standards	One-time or periodic	Applicable to
Periodic self-inspection for DER compliance verification (report prepared by PE): - DER as-built evaluation - Interconnection equipment device settings submitted to Duke Energy - Proof of clear POI access * MV AC construction quality inspection is NOT required **Periodic interconnection tests:** - Cease-to-energize test - Verify any other required operational functions	NCIP-P 6.5.3 NCIP-P Attachment 4 (IEEE 1547) IEEE 1547, IEEE 1547.1	Periodic (intervals TBD; longer than annual)	All DER post commissioning

Self-inspection for Previously Inspected Generating Facilities After Significant Modification

Description and General Requirements

- The requirements will be mostly the same as the program for previously uninspected facilities, except on an as-needed basis when there is significant MV re-construction, or major equipment change.

Activity/Requirement	Reference Standards	One-time or periodic	Applicable to
Depending on the scope of MV re-construction or equipment change, part or all of the following requirements may apply: - Provide a description, and a design & inspection report sealed by a PE, addressing the re-construction work. - Provide a description, photo of nameplate, and an updated interconnection equipment settings using the Excel template, addressing the equipment change. - Perform commissioning test. The cease-to-energize test is required at minimum. The scope of test may include more tests per the applicable requirements as defined in IA or IEEE 1547 at the time of original commercial operation date.	NCIP-P 6.5.3 NCIP-IA 2.1.3 and as it references 3.4.4 IEEE 1547 IEEE 1547.1	One-time After significant work on facility medium voltage equipment or interconnection equipment change	All DER post commissioning

Self-inspection for Previously Inspected Generating Facilities After PQ/Reliability Event

Description and General Requirements

- Duke will consider self-inspection as one of the options when Duke identifies or becomes aware of that a DER facility is causing power quality or reliability problem on the circuit (per NCIP 6.5.4).

Activity/Requirement	Reference Standards	One-time or periodic	Applicable to
Depending on the findings and action items from the post-event investigation, the following requirements may be included in the scope of self-inspection (require PE): - MV AC side construction quality inspection - DER as-built evaluation - Interconnection equipment device settings submitted to Duke Energy - Perform commissioning test. * Depending on severity of the impact from the PQ/Reliability event, Duke may need to inspect the facility rather than waiting for self-inspection.	NCIP-P 6.5.4	One-time After identified condition of concern at facility	All DER post commissioning

Attachment E

Self-inspection for new DER facilities

- Duke believes once the self-inspection for previously uninspected sites is proven to be effective, the program will be easily transitioned to use for new generating facilities.
- The requirements will be different from the presented self-inspection plan for old sites.
- We will work on it through TSRG in 2021.

Currently Existing Process for new PV sites (put in table format)

Activity/Requirement	Reference Standards	One-time or periodic	Applicable to
Interconnection Inspection (performed by Advanced Energy): -MV AC side construction quality inspection, to Duke Energy construction standards -DER as-built evaluation and evaluation of interconnection equipment device settings against IA requirements	NCIP-P 6.5.1 NCIP-IA 1.5.4 NCIP-IA 2.1.3 IEEE 1547	One time (at time of initial interconnection)	DER with IAs with specific reference to Duke construction specifications (COD ~post-2017)
Commissioning tests (performed by Advanced Energy and Duke Energy): - Phase checking - Inverter setting onsite verification - Cease-to-energize test - In-rush mitigation device operation The scope of commissioning test may expand as the IEEE 1547-2018 implementation plan is under development.	NCIP-P 6.5.1 NCIP-IA 2.1.3 IEEE 1547 IEEE 1547.1	One time (at time of initial interconnection)	DER with IAs with specific reference to Duke construction specifications (COD ~post-2017)

Attachment E

Agenda

- 4th Quarter Solar Commissioning Update
- Self-inspection Process Update
- Expected Timeline
- Q&A, open discussion

Expected Timeline

- Q1 – Q3, 2020 – The self-inspection process and supporting documentation have been drafted and revised with inputs from TSRG.
- November, 2020 – Duke plans to finalize the process document, instruction manual, report templates for the "Self-inspection for Previously Uninspected Generating Facilities".
- Starting from Q1, 2021 – Pilot the program with volunteer customers
  - Need more volunteer sites!
  - Duke will work with AE to provide technical training on the topic of self-inspection.
  - Further refine the process with lessons learned from the pilot, through TSRG.
- Start the self-inspection for previously uninspected facilities in 2021.
- Duke plans to share any updates from the ICAP 1547 to TSRG about the "Periodic Self-inspection for Compliance Verification".
  - IEEE expects to have the credential program in place by January 2022.

Attachment E

Agenda

- 4th Quarter Solar Commissioning Update
- Self-inspection Process Update
- Expected Timeline
- Q&A, open discussion

Attachment E

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Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 2

October 28, 2020

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	By	Date	Description
0	AC Williams	3/31/2020	Initial issue
1	AC Williams	7/21/2020	general update prior to July 2020 TSRG meeting
2	AC Williams	10/28/2020	general update prior to Oct. 2020 TSRG meeting

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Section 5.2 – Reactive power capability of the DER........ 15~~14~~

Section 5.3 – Voltage and reactive power control........ 16~~15~~

Section 5.4 – Voltage and active power control........ 18~~17~~

Section 6.2 – Area EPS faults and open phase conditions........ 19~~18~~

Section 6.3 – Area EPS reclosing coordination........ 19~~18~~

Section 6.4.1 – Mandatory voltage tripping requirements........ 20~~19~~

Section 6.4.2 – Voltage disturbance ride-through requirements........ 20~~19~~

Section 6.5.1 – Mandatory frequency tripping requirements .... 21~~20~~

Section 6.5.2 – Frequency disturbance ride-through requirements........ 22~~21~~

Section 7.2.2 – Rapid voltage changes........ 23~~22~~

Section 7.2.3 – Flicker .... 23~~22~~

Section 7.4 – Limitation of overvoltage contribution........ 24~~23~~

Section 10.3, 10.4 – Nameplate and configuration information........ 24~~23~~

Unaddressed Requirements of IEEE 1547-2018 .... 25~~24~~

Appendix – IEEE 1547-2018 Benchmarking .... 26~~25~~

Introduction

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

Consideration of IEEE 1547 sections that could increase interconnection capability

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

Consideration of IEEE 1547 sections that impact grid support

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

Priority of implementing the IEEE 1547 technical specifications and requirements

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	TBD, Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	TBD, Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	TBD, Eval + Comm Test

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TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	TBD, Yes	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	TBD, Yes	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-

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TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-103)	8.1	Unintentional islanding	TBD	Yes	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

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Logistics of Implementing of IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification. Prior to requiring IEEE 1547-2018, Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA may mutually agree to implement those available functions as needed.

Plant requirements

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

Section 1.4 – General remarks and limitations

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

Section 4.2 – Reference points of applicability (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling) and the PoC (point of connection) is the RPA for net meter installations.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:

a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*

b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.

For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]

Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]

For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. The RPA for UDER is the PCC (point of common coupling at the utility interconnection point) and the PoC (point of connection) is the RPA for the net meter installations. ~~The approved UDER transformer configurations all maintain zero sequence continuity.~~ Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: To be determined.

Duke plans to review DER design documents to verify the DER meets this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

Section 4.3 – Applicable voltages

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that

RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

Section 4.5 – Cease to energize performance requirement

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

~~For UDER, Duke Energy is still considering implementing the cease to energize at the inverter or disconnecting at the local EPS.~~

A DER can be directed to cease to energize and trip by changing the Permit service setting to “disabled” as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section. ~~The Binary Output is sent via SCADA to open inverter(s) breaker and is already implemented.~~

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

This section is ready to be implemented.

Section 4.6 – Control capability requirements

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the capabilities in the following sections as written:

4.6.1 Capability to disable permit service

4.6.2 Capability to limit active power

4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

For UDER, Duke Energy is still considering implementing the ~~cease to energize~~permit service at the inverter or disconnecting at the local EPS.

Application to RDER has not been assessed.

Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables.

Duke does not plan to implement real-time control during the initial implementation of the Standard. Significant technical studies are required to address concerns and consider remote real-time control of the active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Interoperability requirements: The present automation controller implementation uses an Analog Output sent via SCADA to control active power.

Verification and test requirements: To be determined.

Duke plans to review type tests, design documents, and equipment specification to identify the capability of the DER to meet this performance requirement. Duke will evaluate if the existing inspection and commissioning test process is sufficient to verify performance and the applicable test requirements of IEEE 1547.1 will be considered.

Implementation of this section requires integrating verification requirements into the overall commissioning test program.

Section 4.7 – Prioritization of DER responses

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design document to evaluate if a DER can meet this requirement.

Duke plans to finalize the scope of inspection and commissioning process to this requirement, following review and incorporation of the commissioning tests requirements in IEEE 1547.1-2020 and UL 1741 SB.

Implementation of this section requires integrating verification requirements into the overall commissioning test program.

Implementation of this section includes establishing the verification requirements.

Section 4.8 – Isolation device

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

Section 4.9 – Inadvertent energization of the Area EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

Section 4.10 – Enter service

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.10.2 Enter service criteria

4.10.3 Performance during entering service

4.10.4 Synchronization

Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

The following criteria will be developed for 4.10.2 and 4.10.3:

Enter service value	**RDER setting (Service tx sec)**	**UDER setting (DER tx pri)**
Minimum Voltage	≥ 0.917 p.u.	≥ p.u.
Maximum Voltage	≤ 1.05 p.u.	≤ p.u.
Minimum Frequency	≥ 59.5 p.u.	≥ p.u.
Maximum Frequency	≤ 60.1 p.u.	≤ p.u.

Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The following time delays shall be used:

Enter service value	**RDER setting (seconds)**	**UDER setting (seconds)**
Enter Service Delay	300	300

The energy storage DER (ESS) rate of change duration is based on 120 MW/minute, which is 2 MW/second.

Rate of Change Duration	**RDER setting (seconds)**	**UDER setting (seconds)**
ESS ≤ 1 MW	~~1~~5	-
ESS > 1 MW and ≤ 10 MW	-	5
ESS > 10 MW	-	10

Interoperability requirements: To be determined.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement.

For 4.10.4, Duke plans to review type tests results and design document to evaluate DER's synchronization capability meeting this requirement. Duke also plans to expand the scope of inspection and commissioning process to test DER for this requirement, following the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position and~~,~~ applying the interoperability functionality in the local interface~~, and integrating verification requirements into the overall commissioning test program~~.

Section 4.11 – Interconnect integrity

Duke Energy requires the DER to meet the requirements of all the following subsections:

4.11.1 Protection from electromagnetic interference
4.11.2 Surge withstand performance
4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

Section 4.12 – Integration with Area EPS grounding

~~Duke must determine the final technical requirements. If needed, Duke expects to address these in the Method of Service Guidelines.~~

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below:

Primary Winding Type (HV)	Secondary Winding Type (LV)	Zero Seq Maintained PCC to POC	Allowed for DER Interconnection

			Inverter	Rotating
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

~~Consider adding discussion of maintaining Zero sequence continuity through the winding configurations and continuity between the PCC and the PoC.~~

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented. ~~Implementation of this section requires publishing the final position.~~

Section 5.2 – Reactive power capability of the DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is available in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard, which is a power factor of 0.90 and the same as transmission generators. Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The capability information shall be provided on an inverter capability curve (P-Q graph) and shall be based on an ambient temperature of 35° C or higher and at the rated voltage of the device. Provide any specific numerical data that defines critical points on the chart. Those include the Nameplate and Configuration active and reactive power parameters as noted in the Standard.

These details for supplemental devices are tentative and there are details and clarifications that Duke still needs to address.

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

If the DER includes supplemental devices, capability data must be provided for each device at an ambient temperature of 35° C or higher and at the rated voltage. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a description and power flow model of the device. If the supplemental devices are static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

For large scale DER that provide the utility to DER transformer, the composite capability curve shall be provided on the secondary side. In that case, the DER must supply all the Duke required transformer modeling information. For net metered interconnections, the composite capability curve shall be provided on the voltage base of the service transformer secondary.

Additionally, along with the individual and composite capability curves, the DER must include any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions).

At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources centrally. However, there is some expectation that functionality may be necessary within the life of the DER, so there are interoperability requirements for both autonomous operation as well as remote control and adjustment of setpoints. The interoperability requirements for remote control are expected to include those for autonomous operation.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

Section 5.3 – Voltage and reactive power control

The Standard lists several forms of reactive power control:

- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode
- Active power-reactive power mode

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings.

In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER. No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2020. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision. Duke is developing the objectives for the second volt-var study.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the VAR priority mode and reactive power mode, and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation. For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints for each mode.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

Section 5.4 – Voltage and active power control

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

Section 6.2 – Area EPS faults and open phase conditions

> Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.
>
> This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: To be determined.

> Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

Section 6.3 – Area EPS reclosing coordination

> Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.
>
> This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

Section 6.4.1 – Mandatory voltage tripping requirements

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

Section 6.4.2 – Voltage disturbance ride-through requirements

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

Section 6.5.1 – Mandatory frequency tripping requirements

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

Section 6.5.2 – Frequency disturbance ride-through requirements

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

This function is still under evaluation. A specification of the droop, deadband, and associated parameters may be needed.

6.5.2.8 Inertial response

Duke Energy has not determined the guidelines for this subsection.

Interoperability requirements: To be determined.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

Section 7.2.2 – Rapid voltage changes

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.

Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test). Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

Section 7.2.3 – Flicker

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

Section 7.4 – Limitation of overvoltage contribution

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

Section 10.3, 10.4 – Nameplate and configuration information

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
  - The rating is the most capacity the system is designed to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.

- Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.
- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

Unaddressed Requirements of IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

Appendix – IEEE 1547-2018 Benchmarking

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

Table B.1. Benchmarking of IEEE 1547-2018 functionalities implementation

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

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IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

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Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Duke Energy

Duke Energy Carolinas and Duke Energy Progress

Distributed Energy Technology

DER Technical Standards

Revision 2

October 28, 2020

Implementation of IEEE 1547-2018 Guidelines for Duke Energy Carolinas and Duke Energy Progress

Revision	By	Date	Description
0	AC Williams	3/31/2020	Initial issue
1	AC Williams	7/21/2020	general update prior to July 2020 TSRG meeting
2	AC Williams	10/28/2020	general update prior to Oct. 2020 TSRG meeting

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DUKE ENERGY.

Introduction

Duke Energy seeks to implement smart inverter technical specifications and requirements as defined in the updated IEEE Standard 1547-2018, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems (IEEE 1547 or the Standard). This document focuses only on the distributed energy resources (DER) connected to the distribution system and not those connected to the transmission or bulk power system (BPS). In North and South Carolina, the implementation of IEEE 1547 is focused on large utility scale DER (UDER) because there had been significant number of those installations. Some of IEEE 1547 requirements are also applicable to the smaller retail and residential DER (RDER). If there are any variations in application of the Standard to UDER and RDER, those conditions will be noted in this document.

Note to the format of this document. This guideline is meant to be a living document. For now, it captures where Duke Energy is in the process of implementing IEEE 1547-2018. This document notes sections of the standard that require no additional analysis or review and those that are under review and those that must still be reviewed. In sections highlighted like this paragraph, there will be a brief discussion of the ongoing work to be concluded to address implementation of that Standard section.

The standard is an inverter Standard and not a utility standard, therefore many parts of the Standard can be implemented by Duke Energy simply by adopting IEEE 1547-2018 as the applicable standard for Duke Energy inverter based interconnections. However, there are some sections of the Standard that require input or specifications from the utility. The Standard specifies inverter capabilities and functions, but not utilization. The purpose of this document is to clarify any additional information for utilization.

The standard is applicable to DER connected at the primary or secondary distribution system voltage levels. However, some of the Standard requirements are based on conditions and issues related to the BES. There can be situations where the aggregate distribution DER capacities are large enough to impact the NERC BES reliability. In those cases, BES requirements are implemented in DER connected to the distribution system. However, these requirements are not directly distribution requirements, but BES requirements applied at the distribution power system level. The interaction between the BES and the distribution system is well covered in the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018. The guideline recommends that the BPS entities (BA, RC, PC, TP) coordinate with the Distribution Providers (DP) to achieve successful implementation of the Standard.

This Duke Energy Guideline is applicable to DER located in the Duke Energy service territories in North Carolina and South Carolina. The Guidelines have been developed based on input and comments from TSRG stakeholders.

Consideration of IEEE 1547 sections that could increase interconnection capability

The following IEEE 1547 controls or functions are the primary functions that could potentially increase the amount of DER capacity (higher penetration) that can interconnect with minimal feeder upgrades:

i) 4.6.2 Capability to limit active power
ii) 5.3 Voltage and reactive power control
iii) 5.4 Voltage and active power control

While power quality issues can still restrict interconnection, the voltage and reactive power controls are a potential mitigation to those issues too.

While there are other inverter functions that improve reliability of the interconnection, the inverter functions listed above would be the primary drivers for adding more DER capacity to a feeder. Therefore, these functions were assigned a higher priority to review and analyze.

Consideration of IEEE 1547 sections that impact grid support

In addition to prioritizing assessment of those sections of IEEE-1547 that could increase interconnection capability, the Companies are also prioritizing those sections that could impact grid support. The 2003 version of the standard created reliability concerns by not providing voltage regulating capability and tripping for abnormal system conditions. While the 2014 version addressed some of the grid reliability concerns, 2018 provides even more inverter capabilities. Also, documents such as the NERC Reliability Guideline: Bulk Power System Reliability Perspectives on the Adoption of IEEE 1547-2018 focus "on ensuring reliable operation of the BPS under increasing penetrations of BPS-connected inverter-based resources as well as distributed energy resources (DERs)." One objective of such documents is to encourage timely adoption of the IEEE 1547-2018 that are likely to impact or support the BPS.

The priority of review of the Standard sections identified in the table is consistent with this industry guidance in that many of the first and second priority selected topics were noted in the NERC guideline as well. Sections 4.2 and 4.10.2 are fourth priority for Duke, but that is mainly because these topics are thought to be more straightforward to address and will likely not require significant evaluation. Interoperability was noted by NERC and Duke plans to address that on a topic by topic basis rather than as one stand-alone interoperability topic. In this way, interoperability is addressed concurrent with the technical considerations for each topic.

The following topics are yet unranked by Duke, but they are in the NERC guideline: 6.4.2.7, 6.5.2.8, 8.1, 8.2. Section 6.4.2.7 was added to the Duke list after the NERC guideline review. These were not ranked during the Duke process because of the lower priority placed on them by the TSRG stakeholders and Duke. These are also topics that need more time and investigation by the industry, so addressing some of the better understood and higher prioritized items first is a reasonable path forward.

Priority of implementing the IEEE 1547 technical specifications and requirements

There are many aspects of implementing the Standard that must be considered. The technical specifications and requirements must be understood and assessed to determine if there is a need to clarify any technical points for consistent application across the Duke system. Duke subject matter experts, TSRG stakeholders, NC Public Staff, and industry documents were included in the activity to set priority for the various Standard sections. The areas of the Standard that stand out as most important are the ride through capability and voltage and reactive power controls.

Below is the priority order at this time considering all TSRG input. If there is no priority stated in the list, then the priority of those items is yet to be assigned. Note that the priority group and the assigned Duke identification number[1] for that item are both in the first column. The remaining IEEE 1547-2018 clauses and sections that do not have a priority assigned will be undertaken following the completion of the higher priority topics. The three columns on the far right side of the table summarize the status for the technical, interoperability, and verification and test aspects for each Standard topic. Many of the summaries are not the final decision because the topic requires more analysis and assessment. However, this table still provides a general overview.

[1] Only the prioritized Duke identification numbers represent the sequence of evaluation, and are numbered less than 100. Numbers greater than 100 are temporarily assigned to the topic until that topic is given a specific priority.

Duke Energy Selected Order of Precedence for IEEE 1547 Sections

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
1 (DUK-01)	5.2	Reactive power capability of the DER	Category B 35° C ambient or higher at rated voltage	No Reqmt	Eval + Comm Test
1 (DUK-02)	5.3	Voltage and reactive power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-03)	5.4.2	Voltage-active power control	Study in progress	Yes	Eval + Comm Test
1 (DUK-04)	7.4	Limitation of overvoltage contribution	Accept 1547 with additional requirements	No Reqmt	Eval + Comm Test
1 (DUK-05)	7.2.3	Power Quality, Flicker	Accept 1547 in conjunction with continued use of IEEE 1453	No Reqmt	Eval + Comm Test
1 (DUK-06)	7.2.2	Power Quality, Rapid voltage change (RVC)	Continue existing criteria and policy	TBD	TBD, Eval + Comm Test
2 (DUK-07)	6.4.1	Mandatory voltage tripping requirements (OV/UV)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-08)	6.5.1	Mandatory frequency tripping requirements (OF/UF)	Have existing setpoints; new 1547 setpoint study in progress	TBD	Eval + Comm Test
2 (DUK-09)	6.4.2	Voltage disturbance ride-through requirements	Study in progress	TBD	Eval + Comm Test
2 (DUK-10)	6.5.2	Frequency disturbance ride-through requirements	Study in progress	TBD	TBD, Eval + Comm Test
2 (DUK-11)	6.5.2.7	Frequency-droop (frequency-power) capability	Evaluation has not begun	No Reqmt	TBD, Eval + Comm Test
2 (DUK-12)	6.5.2.6	Voltage phase angle changes ride-through	Study in progress	No Reqmt	TBD, Eval + Comm Test
3 (DUK-13)	4.5	Cease to energize performance requirement	Accept 1547 as written	No Reqmt	Eval + Comm Test
3 (DUK-14)	4.6.1	Capability to disable permit service	Accept 1547 as written	Yes	TBD, Eval + Comm Test
3 (DUK-15)	4.6.2	Capability to limit active power	Accept 1547 as written	Yes	TBD, Eval + Comm Test
4 (DUK-16)	6.5.2.5	Rate of change of frequency (ROCOF)	Study in progress	TBD	TBD, Eval + Comm Test

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
4 (DUK-17)	4.2	Reference points of applicability (RPA)	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval.
4 (DUK-18)	4.3	Applicable voltages	Accept 1547 as written; consider clarifications	Yes	TBD, Eval.
4 (DUK-19)	4.10.2	Enter service criteria // 6.6 Return to service after trip	Accept 1547 as written; consider clarifications	TBD, Yes	TBD, Eval + Comm Test
4 (DUK-20)	4.10.3	Performance during entering service	Accept 1547 as written; consider clarifications	TBD, Yes	Eval + Comm Test
4 (DUK-21)	4.10.4	Synchronization	Accept 1547 as written; consider clarifications	No Reqmt	TBD, Eval + Comm Test
4 (DUK-22)	4.11.3	Paralleling device	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-23)	4.9	Inadvertent energization of the Area EPS	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-24)	6.3	Area EPS reclosing coordination	Accept 1547 as written; consider clarifications; part of ongoing study	No Reqmt	Eval.
5 (DUK-25)	6.2	Area EPS faults and open phase conditions	Accept 1547 as written; consider clarifications; part of ongoing study	TBD	Eval + Comm Test
5 (DUK-26)	4.12	Integration with Area EPS grounding	Accept 1547 with clarifications	No Reqmt	Eval.
5 (DUK-27)	4.7	Prioritization of DER responses	Accept 1547 as written	No Reqmt	TBD, Eval + Comm Test
5 (DUK-28)	4.8	Isolation device	Accept 1547 as written	No Reqmt	Eval + Comm Test
5 (DUK-29)	4.11.1	Protection from electromagnetic interference	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-30)	4.11.2	Surge withstand performance	Accept 1547 as written	No Reqmt	Type Test
5 (DUK-31)	4.6.3	Execution of mode or parameter changes	Accept 1547 as written	TBD, Yes	TBD, Eval + Comm Test
- (DUK-101)	9	Secondary network	Duke does not currently have these	No Reqmt	-
- (DUK-102)	11.4	Fault current characterization	TBD	No Reqmt	-

TSRG Priority Order (Duke ID)	IEEE 1547 Section	IEEE 1547-2018 Topic	Technical Position Summary	Interoperability Summary	Test and Verification Summary
- (DUK-103)	8.1	Unintentional islanding	TBD	Yes	-
- (DUK-104)	8.2	Intentional islanding	TBD	Yes	-
- (DUK-105)	11	Test and verification	TBD	-	-
- (DUK-106)	10.2	Monitoring, control, and information exchange requirements	TBD	Yes	-
- (DUK-107)	10.5	Monitoring information	TBD	Yes	-
- (DUK-108)	6.4.2.5	Ride-through of consecutive voltage disturbances	TBD	No Reqmt	-
- (DUK-109)	6.4.2.6	Dynamic voltage support	TBD	No Reqmt	-
- (DUK-110)	6.5.2.8	Inertial response	TBD	No Reqmt	-
- (DUK-111)	10.1	Interoperability requirements	TBD	Yes	-
- (DUK-112)	10.3	Nameplate Information	TBD	Yes	-
- (DUK-113)	10.4	Configuration information	TBD	Yes	-
- (DUK-114)	10.6	Management information	TBD	Yes	-
- (DUK-115)	10.7	Communication protocol requirements	TBD	Yes	-
- (DUK-116)	10.8	Communication performance requirements	TBD	Yes	-
- (DUK-117)	10.9	Cyber security requirements	TBD	Yes	-
- (DUK-118)	7.3	Limitation of current distortion	TBD	TBD	-
- (DUK-119)	4.13	Exemptions for Emergency Systems and Standby DER	TBD	TBD	-
- (DUK-120)	6.4.2.7	Restore output with voltage ride-through	TBD	No Reqmt	0

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Logistics of Implementing of IEEE 1547-2018

After the technical aspects of each Standard section are understood, Duke Energy can then determine the necessary changes to implement that section. This could vary from taking no action, to updating documentation, to changing work, study, and operational practices. Additionally, a consequence of more inverter functions will be the necessary increase in interoperability requirements as well as DER equipment and DER system verification and testing to confirm design and functional requirements. There are many aspects to consider before implementing each 1547 section. Because the actions to implement each section can vary widely, the implementation will be addressed in each section rather than as a whole for the entire Standard.

It is understood that many of the functions will not be available until IEEE 1547-2018 certified inverters are tested and available to the market. At that time, Duke Energy shall require all inverters to be IEEE 1547-2018 certified. All functions and requirements may not be applicable or implemented at the time the inverters become certified or that Duke Energy requires the certification. Prior to requiring IEEE 1547-2018, Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA may mutually agree to implement those available functions as needed.

Plant requirements

Guidelines must consider how all sections may apply if implemented on a plant-scale with a power plant controller rather than at the individual inverter units. There may need to be some tests for verification that the plant controller performs the intended functions and that the underlying inverters to not behave contrary to the plant controller configuration or commands.

Note that in the following part of this document, the title of each section is the IEEE 1547-2018 section or subsection number and title.

Section 1.4 – General remarks and limitations

Duke Energy accepts the scope of the Standard as specified in this section. For UDER, the single point of common coupling (PCC) is located at the boundary between the utility electric power system (EPS) and the local EPS or DER EPS.

The technical specifications and requirements for some performance categories are specified by general technology-neutral categories. For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy requires the following normal performance category:

Voltage and Reactive Power Category B

For categories related to response to Area EPS abnormal conditions, Duke Energy requires the following abnormal operating performance categories:

Synchronous generation	Category I
Induction generation	Mutual agreement
Inverter-based generation	Category III*
Inverter-based storage	Category III*

This section shall be applicable once 1547-2018 inverters are certified and required or if by mutual agreement between Duke Energy and the DER Owner for inverters certified to IEEE 1547a-2014 or UL 1741 SA.

* Final determination for the Category has not been made. More analysis is required and included as part of a study conducted jointly between the Duke Protection and Transmission Planning groups. This work includes a significant effort to model the system, perform iterative studies, and perform research. The main focus is on Category II and that is expected to be the minimum requirement for IBR. With the amendment to IEEE 1547a-2020 approved and many utilities standardizing on Category III, that is the most likely selection.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Independent laboratory certifications that attest to the normal and abnormal categories shall satisfy verification for this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

Section 4.2 – Reference points of applicability (RPA)

Duke Energy requires the RPA for all performance requirements for UDER to be the PCC (point of common coupling) and the PoC (point of connection) is the RPA for net meter installations.

Pending analysis: The expectation is that Duke can accept the Standard as written, but Duke must still determine if there are any applicable exceptions or clarifications needed given this portion of section 4.2:

> Alternatively, for Local EPSs where zero sequence continuity[27] between the PCC and PoC is maintained and either of the following conditions apply, the RPA for performance requirements of this standard may be the *point of DER connection* (PoC), or by mutual agreement between the *Area EPS* operator and the *DER operator*, at any point between, or including, the PoC and PCC:
>
> a) Aggregate DER nameplate rating of equal to or less than 500 kVA, *or*
>
> b) Annual average load demand[28] of greater than 10% of the aggregate DER nameplate rating, and where the Local EPS is not capable of, or is prevented from, exporting more than 500 kVA for longer than 30 s.
>
> For all other Local EPSs meeting either of the conditions a) or b) above but not meeting the requirement for zero sequence continuity, the RPA for performance requirements other than the response to *Area EPS* abnormal conditions specified in 6.2 and 6.4 shall be the PoC, or by mutual agreement between the *Area EPS operator* and the *DER operator*, at any point between, or including, the PoC and PCC. The RPA for performance requirements of 6.2 and 6.4 shall be a point between, or including, the PoC and PCC that is appropriate to detect the abnormal voltage conditions.[29, 30]
>
> Where the RPA is not at the PCC, any equipment or devices in the Local EPS between the RPA and the PCC shall not preclude the DER from meeting the disturbance ride-through requirements specified in 6.4.2 and 6.5.2.[31]
>
> For Local EPS where aggregate DER nameplate rating is greater than 500 kVA, and annual average load demand[28] is greater than 10% of the aggregate DER nameplate rating, and the Local EPS is capable of, and is not prevented from, exporting more than 500 kVA for longer than 30 s, the RPA shall be the PCC and

The final position must consider the variety of RDER and UDER interconnections and identify the RPA for each. In practice, the interconnections have been very straightforward. The default RPA is the PCC. The RPA for UDER is the PCC (point of common coupling at the utility interconnection point) and the PoC (point of connection) is the RPA for the net meter installations. Note that Section 4.12 also addresses grounding and zero sequence continuity.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: To be determined.

Duke plans to review DER design documents to verify the DER meets this requirement.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

Section 4.3 – Applicable voltages

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the section is implemented as written. The expected outcome is that

RDER parameters shall be monitored at the inverter terminals and UDER parameters shall be monitored at the EPS voltage level and used for inverter functions.

Interoperability requirements: Applicable voltages are provided to the local DER interface with Duke Energy.

Verification and test requirements: To be determined.

The applicable voltage should be identified in the interconnection process. Duke plans to review design document to verify the DER meet this requirement.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

Section 4.5 – Cease to energize performance requirement

Duke Energy requires cease to energize capability (not delivering power during steady-state or transient conditions) in accordance with the Standard.

A DER can be directed to cease to energize and trip by changing the Permit service setting to "disabled" as described in IEEE 1547 subsection 4.10.3.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to identify the interconnection device that provides the cease-to-energize function. The existing inspection and commissioning process tests to verify the device meets the performance requirement.

This section is ready to be implemented.

Section 4.6 – Control capability requirements

Duke Energy will consider if there is a need to clarify any technical points for the final version of the guideline, but the expectation is that the capabilities in the following sections will be adopted as written.

Duke accepts the capabilities in the following sections as written:

- 4.6.1 Capability to disable permit service
- 4.6.2 Capability to limit active power
- 4.6.3 Execution of mode or parameter changes

This section of the Standard applies to all DER 250 kW or greater or DER with a local DER communication interface.

For UDER, Duke Energy is still considering implementing the permit service at the inverter or disconnecting at the local EPS.

Application to RDER has not been assessed.

Note that 4.6.2 is essentially part of the system impact study (SIS) process now because the maximum active power capacity (import or export) is often calculated during the SIS if the requested DER capacity is not possible without upgrades. The Standard defines the active power limit as a percentage of the Nameplate Active Power Rating. Duke interprets the referenced rating as the Nameplate Active Power Rating at unity power factor. Consider too that the active power limit is manually set and Duke does not have the capabilities to adjust the limit based on time of day, load, or other variables.

Duke does not plan to implement real-time control during the initial implementation of the Standard. Significant technical studies are required to address concerns and consider remote real-time control of the active power limit. However, it is reasonable to make provision for this potential capability when designing the monitoring and control capabilities of the communication interface.

Interoperability requirements: The present automation controller implementation uses an Analog Output sent via SCADA to control active power.

Verification and test requirements: To be determined.

Duke plans to review type tests, design documents, and equipment specification to identify the capability of the DER to meet this performance requirement. Duke will evaluate if the existing inspection and commissioning test process is sufficient to verify performance and the applicable test requirements of IEEE 1547.1 will be considered.

Implementation of this section requires integrating verification requirements into the overall commissioning test program.

Section 4.7 – Prioritization of DER responses

Duke Energy expects IEEE 1547-2018 compliant inverters to meet all prioritization requirements of this section of the Standard.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design document to evaluate if a DER can meet this requirement.

Duke plans to finalize the scope of inspection and commissioning process to this requirement, following review and incorporation of the commissioning tests requirements in IEEE 1547.1-2020 and UL 1741 SB.

Implementation of this section requires integrating verification requirements into the overall commissioning test program.

Implementation of this section includes establishing the verification requirements.

Section 4.8 – Isolation device

Duke Energy requires isolation devices per the Interconnection Agreement, Method of Service Guidelines, and other interconnection documents. This is a current requirement that is unchanged by IEEE 1547-2018.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Existing site evaluation and inspection shall satisfy verification for this requirement.

This section is ready to be implemented.

Section 4.9 – Inadvertent energization of the Area EPS

Duke Energy requires DER not to energize the utility EPS when the utility EPS is de-energized. When there is a planned and designed intentional island, per Section 8.2 Intentional Islanding, that configuration is not considered inadvertent.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke will only accept type-tested DER for small scale installations like RDER. For UDER, the existing inspection and commissioning process covers this requirement.

This section is ready to be implemented.

Section 4.10 – Enter service

Duke Energy requires the DER to meet the requirements of all the following subsections:

- 4.10.2 Enter service criteria
- 4.10.3 Performance during entering service
- 4.10.4 Synchronization

Duke must still determine the enter service criteria and enter service time delays. Note that while the Standard mentions Range B of ANSI C84.1, that voltage is at the service level (low side of the service transformer) and not at the primary side. Therefore, the settings in the Standard would be more relevant to RDER than UDER that has the RPA and PCC at the primary side of the DER transformer. The RDER values are common in the industry and are Standard defaults.

The following criteria will be developed for 4.10.2 and 4.10.3:

Enter service value	**RDER setting (Service tx sec)**	**UDER setting (DER tx pri)**
Minimum Voltage	≥ 0.917 p.u.	≥ p.u.
Maximum Voltage	≤ 1.05 p.u.	≤ p.u.
Minimum Frequency	≥ 59.5 p.u.	≥ p.u.
Maximum Frequency	≤ 60.1 p.u.	≤ p.u.

Duke will compare the final voltage trip and ride through settings for UDER with the Standard default settings. Assuming they are compatible, UDER will adopt the same Standard default values.

The following time delays shall be used:

Enter service value	**RDER setting (seconds)**	**UDER setting (seconds)**
Enter Service Delay	300	300

The energy storage DER (ESS) rate of change duration is based on 120 MW/minute, which is 2 MW/second.

Rate of Change Duration	**RDER setting (seconds)**	**UDER setting (seconds)**
ESS ≤ 1 MW	5	-
ESS > 1 MW and ≤ 10 MW	-	5
ESS > 10 MW	-	10

Interoperability requirements: To be determined.

Duke will evaluate if there is value in monitoring the enter service settings.

Verification and test requirements: For 4.10.2 and 4.10.3, Duke plans to verify the enter service and return to service settings in the field. The existing inspection and commissioning process tests to verify DER meets this requirement.

For 4.10.4, Duke plans to review type tests results and design document to evaluate DER's synchronization capability meeting this requirement. Duke also plans to expand the scope of inspection and commissioning process to test DER for this requirement, following the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final technical position and applying the interoperability functionality in the local interface.

Section 4.11 – Interconnect integrity

Duke Energy requires the DER to meet the requirements of all the following subsections:

- 4.11.1 Protection from electromagnetic interference
- 4.11.2 Surge withstand performance
- 4.11.3 Paralleling device

Duke Energy does not have additional clarifications of these subsections.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: They standard type-testing is satisfactory for Duke.

This section is ready to be implemented.

Section 4.12 – Integration with Area EPS grounding

Duke accepts the Standard; that the grounding scheme of the DER interconnection shall be coordinated with the ground fault protection of the Area EPS. Duke's system is multi-grounded and the DER facilities and design must be compatible with the EPS. Each interconnection is reviewed for ground fault protection and for limiting the potential for creating over-voltages on the Area EPS.

Approved distribution connected utility scale DER transformer winding configurations are listed below:

Primary Winding Type (HV)	**Secondary Winding Type (LV)**	**Zero Seq Maintained PCC to POC**	**Allowed for DER Interconnection**	
			Inverter	**Rotating**
Wye-grounded	Wye-grounded	Yes, (w/4-wire LV)	Yes	Yes
Wye-grounded	Wye	No	Yes	No
Wye-grounded	Delta	No	No	Yes

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review the design document to evaluate if a DER can meets this requirement. The existing inspection and commissioning test process will cover this.

This section is ready to be implemented.

Section 5.2 – Reactive power capability of the DER

Whether or not reactive power capability or voltage control is initially used for the DER, each DER shall submit the required reactive power capability information. This provides the information when it is available in the event that it is needed later.

For categories related to reactive power capability and voltage regulation performance requirements, Duke Energy plans to require the following performance category:

Voltage and Reactive Power Category B

Category B requires a DER reactive power injection capability (lagging) of 44% of nameplate apparent power rating and 44% absorption capability (leading) of nameplate apparent power rating as defined in the Standard, which is a power factor of 0.90 and the same as transmission generators. Because the capability curve limit must be satisfied, the vector sum of the active and reactive powers must not exceed the apparent power capability[2]. The capability information shall be provided on an inverter capability curve (P-Q graph) and shall be based on an ambient temperature of 35° C or higher and at the rated voltage of the device. Provide any specific numerical data that defines critical points on the chart. Those include the Nameplate and Configuration active and reactive power parameters as noted in the Standard.

These details for supplemental devices are tentative and there are details and clarifications that Duke still needs to address.

If the DER includes supplemental devices, capability data must be provided for each device at an ambient temperature of 35° C or higher and at the rated voltage. For a dynamic device, capable of varying output magnitude, a capability curve must be provided with a description and power flow model of the device. If the supplemental devices are static (i.e. a fixed capability), then a curve is not required, but the appropriate capability data must be provided and the type of device identified. Additionally, if there are multiple devices that form the complete DER, a composite capability curve that includes all sources, loads, and supplemental devices shall be provided.

For large scale DER that provide the utility to DER transformer, the composite capability curve shall be provided on the secondary side. In that case, the DER must supply all the Duke required transformer modeling information. For net metered interconnections, the composite capability curve shall be provided on the voltage base of the service transformer secondary.

[2] See the EPRI document "Understanding Watt and Var Relationships in Smart Inverters", 3002015102

Additionally, along with the individual and composite capability curves, the DER must include any factors that limit or de-rate the output of the generator (e.g., collector system voltage limits, auxiliary voltage limits, net meter load voltage limits, current limits, and specific ambient temperature conditions).

At this time, Duke does not have the capability to remotely control or manage distribution connected reactive power resources centrally. However, there is some expectation that functionality may be necessary within the life of the DER, so there are interoperability requirements for both autonomous operation as well as remote control and adjustment of setpoints. The interoperability requirements for remote control are expected to include those for autonomous operation.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to evaluate design documents and equipment specifications to determine reactive power capability. A field test may be required for DER to prove its reactive power capability. Duke expects to follow the commissioning tests requirements in IEEE 1547.1 to cover this topic.

Implementation of this section requires publishing the final position and integrating verification requirements into the overall commissioning test program.

Section 5.3 – Voltage and reactive power control

The Standard lists several forms of reactive power control:

- Constant power factor mode
- Constant reactive power mode
- Voltage-reactive power mode
- Active power-reactive power mode

Constant reactive power is not thought to be a particularly useful control mode. Constant power factor is the broad category of control that includes unity power factor, which can be useful, but is limited by operating at a control point that is not based on feeder conditions. Duke is in the process of performing studies that will focus on voltage-reactive power mode and active power-reactive power mode for UDER. The Duke study will evaluate the application and consequences of these functions.

Part of the study effort is to determine if voltage regulation functions should be activated and how they should be configured. Before using these functions on a widespread basis, Duke Energy will evaluate the system impacts, identify any unanticipated effects, and then assess the control modes and settings.

In North and South Carolina utility scale solar, UDER, is the majority of the solar capacity installed. Therefore, study efforts will focus on that type of facility. In due time, there should be some consideration for residential-scale inverters as well. The reactive control method and settings should consider existing operational requirements as well as mitigation of the high voltages that can occur with the addition of DER. No change can be made on one part of the system that does not affect another part. Therefore, the study will also consider the magnitude of influence the inverter has on voltage, reactive power flow impacts, remediation of impacts, and controlling the impact on the transmission system. Distribution Providers must comply with agreements and requirements of the transmission entities. As such, an evaluation of transmission impacts is important.

Significant technical studies are required to evaluate these functions and analyze the consequences. The studies began at the end of 2019 and will continue in 2020. This will continue to be an agenda item for the TSRG meetings will focus on the most useful control modes and settings that are applied locally in the inverter and are autonomous.

Duke Energy has reviewed and considered all TSRG and submitted comments up to the date of this revision. Duke is developing the objectives for the second volt-var study.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the VAR priority mode and reactive power mode, and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation. For example, some DER require a 0-100% setpoint while others require an actual value in kVAR. In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While priority can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints for each mode.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-var settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

Section 5.4 – Voltage and active power control

The main requirement here involves subsection 5.4.2, Voltage-active power mode. The voltage-active power mode serves as a backup to voltage control. Should an unexpected high voltage condition arise, or the voltage cannot be controlled by the local reactive resources, the voltage-active power control will reduce the DER active power to assist with voltage control

The settings and specifications for voltage-active power control are included with the study discussed for Section 5.3.

Interoperability requirements: To be determined.

Even with autonomous operation there will be some requirements to communicate the mode and possibly other information. Because those requirements are not known at this time, Duke must perform additional analysis and interface testing for autonomous operation.

Duke has the initial I/O points for active power control. The SCADA interface required and operations and functional requirements are still to be determined.

In the future, there may be value in providing the necessary controls for remote utility control. That is second priority to autonomous operation, but that would require even more controls and monitoring. While the mode can be enabled/disabled with a Binary Output, separate Analog Outputs must be used to set the individual control setpoints.

Verification and test requirements: To verify DER compliance to this requirement, Duke will require evaluation of the volt-watt settings and field settings verification. Due to complication of performing voltage tests in the field, Duke does not plan to require field commissioning test on this topic. Operational data may be required to evaluate the DER's performance meeting this requirement.

Additional analysis must be performed before finalizing the Verification and test requirements.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface, and integrating verification requirements into the overall commissioning test program.

Section 6.2 – Area EPS faults and open phase conditions

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: To be determined.

Duke Energy must evaluate if there are any interoperability requirements for this section.

Verification and test requirements: The existing inspection and commissioning process covers the verification of this requirement. Duke plans to continue the practice and refine the process as necessary following the commissioning test requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position, applying the interoperability functionality in the local interface.

Section 6.3 – Area EPS reclosing coordination

Duke Energy has not determined the guidelines for this section. While the Standard may be accepted as written, there may need to be clarifications.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: For large scale DER that is equipped with a Duke PCC recloser, such coordination will be considered under the Duke Energy DER Enterprise Standards. For other DER, Duke will follow the commissioning tests requirements in IEEE 1547.1.

Implementation of this section requires publishing the final position.

Section 6.4.1 – Mandatory voltage tripping requirements

Duke Energy has not determined the guidelines for this section.

This is a sub-task of an ongoing project involving the Protection and Transmission Planning groups. There is an enormous effort to model the system, perform iterative studies, perform the research, and evaluate protection settings. Duke Energy is working to determine the best DER recloser protection elements to optimize protection and ride-through performance and establish the abnormal operating performance Categories.

Consensus was reached with Transmission System Planning and Operations for POI Recloser voltage and frequency settings and time delays that provide adequate ride-through for BES events. The team is still reviewing the impact to system protection with the proposed settings.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the voltage trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

Section 6.4.2 – Voltage disturbance ride-through requirements

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal voltage tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

6.4.2.6 Dynamic voltage support

At least one Duke region requires dynamic reactive compensation for transmission connected DER. Application for the distribution system is still under evaluation.

Section 6.5.1 – Mandatory frequency tripping requirements

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

Interoperability requirements: To be determined.

It is expected that these values will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: The existing inspection and commissioning process covers the frequency trip settings field verification and Duke plans to continue that practice. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

Section 6.5.2 – Frequency disturbance ride-through requirements

For sections 6.5.2.1 through 6.5.2.4, concerning frequency ride-through:

Duke Energy has not determined the guidelines for this section, but these requirements are being developed concurrently with Section 6.4.1 – Mandatory voltage tripping requirements.

The Standard also includes several subsections related to frequency. Although Duke Energy considers these requirements mainly as functional specifications for the inverter, Duke Energy does have additional requirements or clarifications.

6.5.2.5 Rate of change of frequency (ROCOF)

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.6 Voltage phase angle changes ride-through

This function, either at the inverter or the utility PCC recloser, is still under evaluation. Duke anticipates adopting the 1547 requirements if that is supported by the ongoing project.

6.5.2.7 Frequency-droop (frequency-power) capability

This function is still under evaluation. A specification of the droop, deadband, and associated parameters may be needed.

6.5.2.8 Inertial response

Duke Energy has not determined the guidelines for this subsection.

Interoperability requirements: To be determined.

It is expected that these values for Section 6.5.2 will be set and not changed remotely, however this position must be evaluated by Duke. Because these are critical protection setpoints, remote visibility of the setting would be a beneficial capability. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements. Note that this setting is incorporated in SUNSPEC MODBUS.

Verification and test requirements: To verify DER compliance, Duke will require evaluation of the DER ride-through settings and field setting verification. Due to complication of performing abnormal frequency tests in the field, Duke plans to perform design evaluation and installation evaluation for the purpose of evaluating conformance of the DER, and currently does not plan to require field commissioning tests on this topic. Operational data collection after a DER or system event may be required to validate proper DER operation. IEEE 1547.1-2020 suggests signal injection test method may be considered if the DER has the provision for this method. Adjustment of the shall-trip settings may be made if verification of the mandatory trip function is required.

Implementation of this section requires publishing the final position and applying the interoperability functionality in the local interface.

Section 7.2.2 – Rapid voltage changes

Duke has an existing process that is part of the system impact study to assess the risk of Rapid Voltage Changes (RVC) and require mitigation if necessary. Duke considers that the existing RVC criteria is consistent with the Standard and does not plan further evaluation.

Interoperability requirements: To be determined.

Based on the type of inrush mitigation used, there could be some status points that are useful for situational awareness. Because requirements are not known at this time, Duke must perform additional analysis before establishing interoperability requirements.

Verification and test requirements: The installation evaluation is currently included in the scope of Duke's interconnection inspection process, but the performance of the mitigation is not currently tested. A power quality meter is required for the field tests. Duke plans to evaluate the DER RVC impact and mitigation performance by reviewing the data collected during the commissioning test (such as cease-to-energize test). Duke will develop a test procedure and criteria to evaluate the performance of a RVC mitigation solution as part of the commissioning tests.

Implementation of this section requires applying the interoperability functionality in the local interface and integrating verification requirements into the overall commissioning test program.

Section 7.2.3 – Flicker

Duke Energy adopts these requirements as written in the Standard. Note that Duke also applies IEEE 1453 recommended practices.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review design document and equipment specification to evaluate the potential flicker cause DER. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1. Operational data collection after a DER or system event may be required to validate proper DER operation.

This section is ready to be implemented.

Section 7.4 – Limitation of overvoltage contribution

Duke Energy adopts these requirements as written in the Standard. The industry has found that the inverter designs are reaching and exceeding the harmonic monitoring capabilities of existing measurement devices. Therefore, Duke Energy requires the DER owner to mitigate all order harmonics to no greater than 0.3% if the harmonics affect other customers. Harmonic limits shall be aggregated and applied during the DER hours of operation.

Interoperability requirements: No specific requirements for this section.

Verification and test requirements: Duke plans to review type tests results and design documents to evaluate the potential overvoltage contribution from DER. Duke plans to develop a test procedure and criteria for transient overvoltage during the commissioning test. A power quality meter is required for the field tests. Duke plans to follow the commissioning tests requirements in IEEE 1547.1.

This section is ready to be implemented.

Section 10.3, 10.4 – Nameplate and configuration information

These sections address the two broad types of information available through the local DER communication interface. The following terms are listed in decreasing order of magnitude. The value of each parameter in the list is greater than or equal to the value of the parameter below it:

Nameplate Apparent Power Maximum Rating
Configuration Apparent Power Maximum Rating
Nameplate Active Power Rating (unity power factor)
Configuration Active Power Rating (unity power factor)

> The list above does not address all the terms in the table. Such a specification is not necessary of every term, but helpful to clarify for some. Duke will consider addressing other terms as needed. Consequently, operational limits and settings, such as the Active Power Limit, cannot be greater than the ratings (not applicable to abnormal or protection settings).

Ratings are considered a permanent characteristic of a device or a system and are characterized by:

- Rating is the full capacity of the equipment or system.
    - The rating is the <u>most</u> capacity the system is <u>designed</u> to provide
- Rating represents a continuous capacity. Operation at the Rating can continue for indefinitely long periods without exceeding design limits and without reducing the life or maintenance interval.
    - Also, there can be short-term ratings that are time limited. Operation within the parameter and time limit does not exceed design limits or negligibly reduce the life or maintenance interval.
- Rating is the base upon which other model, analysis, and inverter parameters are referenced.
- Ratings are a common way to identify and classify devices.

Limits are not included in these sections of the Standard. However, their relationship to and differences from ratings are important. Limits are adjustable, provide boundaries not to be exceeded, and are less than or equal to ratings. Limits are characterized by:

- Limits impose boundaries on device operation, often to restrict operation within ratings.
- Limits can be established or defined by contractual, system design, or physical equipment restrictions.
- Limits are set for a controlled variable and must not be exceeded (e.g. boundary condition).
- Limits are often stated as a percent of the rating (therefore necessitating a fixed rating value).

The Nameplate Active Power Rating is an important design parameter for the DER, but also as an important base parameter for modeling. The same for Nameplate Apparent Power Maximum Rating, for some equipment or models, parameters may be specified in terms of percent of Nameplate Apparent Power or Nameplate Active Power Rating. In cases where operation to the full Nameplate Active Power Rating is not acceptable for the application, then the Configuration Active Power Rating can be set to establish a lower rating. While the minimum of these two values sets the overall rating, it can be important to distinguish between these when it comes to equipment specifications and modeling.

Unaddressed Requirements of IEEE 1547-2018

The remaining IEEE 1547-2018 clauses and sections not discussed above will be undertaken following the completion of the higher priority topics. Concerning the clauses and sections not addressed in this document, Duke Energy expects that the DER shall conform to the Standard itself as written.

Appendix – IEEE 1547-2018 Benchmarking

Duke Energy requested that Navigant Consulting, Inc. to facilitate the stakeholder discussion at the January 2020 TSRG meeting and to perform benchmarking. The following table was developed by Navigant Consulting, Inc.

Table B.1. Benchmarking of IEEE 1547-2018 functionalities implementation

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
6.4.2	Voltage disturbance ride-through requirements	1	1	1
5.3	Voltage and reactive power control	1	1	1
6.5.2	Frequency disturbance ride-through requirements	2	1	1
6.4.1	Mandatory voltage tripping requirements (OV/UV)	1	1	2
5.4.2	Voltage-active power control	1	1	2
6.5.2.7	Frequency-droop (frequency-power) capability	2	1	2
6.5.1	Mandatory frequency tripping requirements (OF/UF)	2	1	2
5.2	Reactive power capability of the DER	1	1	
4.5	Cease to energize performance requirement [Reliability]	3	2	
4.6.1	Capability to disable permit service	3	2	
4.6.2	Capability to limit active power	3	2	
4.10.2	Enter service criteria	4	3	2
7.2.2	Power Quality, Rapid voltage change (RVC)	1	3	
4.10.3	Performance during entering service	4	3	
4.10.4	Synchronization	4	3	
4.2	Reference points of applicability (RPA) [Interconnection]	4	3	
6.5.2.5	Rate of change of frequency (ROCOF)	4	4	1
4.10	Enter service [Reliability] // 6.6 Return to service after trip	4	4	2
6.4.2.6	Dynamic voltage support		4	2
4.3	Applicable voltages [Manufacturer]	4	4	
4.11.3	Paralleling device	4	4	
6.2	Area EPS faults and open phase conditions [Reliability]		4	
6.3	Area EPS reclosing coordination [Reliability]		4	

Attachment G

DUKE ENERGY.

IEEE 1547 Section	Topic	Duke Order (pre-stakeholder)	Minnesota/ Colorado (Xcel Energy)	Ameren / MISO
10.2	Monitoring, control, and information exchange requirements		4	
10.5	Monitoring information		4	
10.1	Interoperability requirements		4	
10.3	Nameplate Information		4	
10.4	Configuration information		4	
10.6	Management information		4	
10.7	Communication protocol requirements		4	
10.8	Communication performance requirements		4	
10.9	Cyber security requirements		4	
11	Test and verification		4	
8.2	Intentional islanding		4	
11.4	Fault current characterization		4	
9	Secondary network		4	
4.6.3	Execution of mode or parameter changes [Manufacturer]		4	
6.5.2.6	Voltage phase angle changes ride-through	2		1
6.4.2.5	Ride-through of consecutive voltage disturbances			1
7.2.3	Power Quality, Flicker	1		
7.4	Limitation of overvoltage contribution	1		
6.5.2.8	Inertial response			
7.3	Limitation of current distortion			
8.1	Unintentional islanding			
4.7	Prioritization of DER responses			
4.8	Isolation device [Interconnection]			
4.11.1	Protection from electromagnetic interference			
4.11.2	Surge withstand performance			
4.12	Integration with Area EPS grounding [Reliability]			
4.13	Exemptions for Emergency Systems and Standby DER			
4.9	Inadvertent energization of the Area EPS [Interconnection]			

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